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FINAL REPORT



# AN ON-LINE COMPUTING CENTER

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Information Processing Laboratory
Rome Air Development Center
Research and Technology Division
Air Force Systems Command
Griffiss Air Force Base, New York

System No.730
Project No. 5581 , Task No. 558104

(Prepared under Contract No. AF30(602)-2762 by Thompson Ramo Wooldridge, Inc., Canoga Park, California; Glen J. Culler and Burton D. Fried)

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## Foreword

This is a final report covering work performed from February 11, 1962 through February 11, 1963 under Contract AF 30 (602) 2762. The objective was to create an on-line computer system allowing direct use of a high speed digital computer by a mathematician or scientist in the solution of problems in his own field of specialization. This has now been accomplished

Of crucial importance is the provision of a direct two-way coupling between the scientist and the computer, allowing the two to interact and strongly influence one another so as to take maximum advantage of the capabilities peculiar to each: the machine's capacity for rapid calculation and data processing and the man's deep understanding of, and experience with his particular problem area. The feedback from computer to user is conventional, involving oscilloscope displays of curves and occasional numbers. The control of the computer by the scientist is also mechanically simple, involving conventional keyboards. However, it is quite sophisticated as regards the organizational concepts, since achievement of the desired close coupling requires elimination of conventional programming procedures with their attendent

"turn-around time" and of conventional programmers, who cannot be expected to translate to the computer the scientist's intuition or his experience in attacking problems in his field.

The report is divided into two parts. The first provides a description of the system from a user's point of view, explaining the general aspects and then giving a fairly detailed specification of the various capabilities and their use, without, however, touching on the underlying computer programs. The second part provides, chiefly for reference purposes, a listing of all programs used in the system and also information concerning the allocation of data within the computer system, the location, by overlay and key, of the individual hand programs described in the first part, etc.

ABSTRACT

An on-line computing system has been developed which allows direct use of a high speed digital computer by mathematicians and scientists in their specialized fields.

This report describes the system in detail from a user's point of view. For reference purposes, the report includes a listing of all computer programs used in the system.

## PUBLICATION REVIEW

**This report has been reviewed and is approved.**

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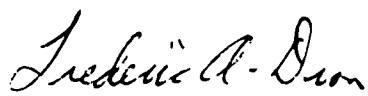
EVALUATION OF FINAL REPORT ON CONTRACT AF30(602)-2762

The contractual effort resulted in a set of techniques that enable a scientist to discover the mathematical approach needed to solve his scientific problems numerically. The techniques allow a scientist to bring to bear his own experience and intuition and to compound them with the computational power of a modern high-speed computer. The scientist not only is able to solve problems that previously could not be solved, but is also heuristically led to deeper insights during the solution process.

The effort thus provides one more tool in the continuing research being done on ways to process data and solve problems using digital computers.

The information from this research effort is already being used to set up a similar facility in Building 240 providing the capability for RADC and other Air Force scientists to solve many of their scientific problems. An additional in-house effort has begun, aimed at adapting the philosophy and techniques developed under the contract to AF Command and Control Systems.



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# A. GENERAL DESCRIPTION OF THE ON-LINE SYSTEM

## I. INTRODUCTION

Despite the impressive achievements in computer hardware and programming techniques in recent years, the most significant gains presently realizable are associated with new approaches to the use, the organization and the logical structure of computers. One line of research has had as its goal the assumption by the computer of certain activities generally associated with human beings; the resultant study of learning machines, adaptive machines, et al has been very fruitful. Quite a different approach has been taken by those who instead seek ways of improving the man-machine communication so that the computer can more effectively assist the man in those jobs (requiring intuition, judgment, evaluation) for which he is best suited. Although no universally accepted nomenclature seems to exist, it is sometimes characterized as a means of getting a man "on-line" with a computer[1)], as opposed to his usual "off-line" status of wading through reams of computer print-out .

Adopting this term, we describe here an operating "on-line" computer research center which provides an unusually close coupling between the man who originates a problem and a (modern, large electronic digital) computer. We hope this example of what can be accomplished using computer hardware well within the existing state-of-the-art will be useful to others concerned with the development of on-line techniques.

This work was initially motivated by the troubles which have been commonly encountered in using a computer to solve research problems whose structure is for the most part unknown and frequently

surprising. It is notoriously difficult to obtain a satisfactory computer program if one does not understand, a priori, the general character of the solution. In fact, information about the general character is often what we really want, rather than quantitative details. It is possible in principle to attempt a kind of experimental mathematics, starting with some promising method of solution and the associated program and modifying one or both in the light of the results obtained. However, the lapse of time between the selection of a new method, or the modification of an old one, and the return of information from the computer to the user is in most cases so long as to make this almost infeasible.

The source of the difficulty is basically the poor communication between the "user" (by which we shall henceforth mean the scientist or mathematician who originates a problem and knows most about it) and the computer, consequent upon considerations of economy and, as well, upon the inherent difficulty of imparting to a programmer the detailed and specialized knowledge one acquires about a particular problem area after working in it for some time. One anticipates a significant improvement in a system, such as that described here, which provides for a rapid, direct, comfortable interchange of information between man and machine. In fact, however, one reaps even greater rewards; if the communication link is established in the proper way it becomes possible for the user to apply, simultaneously, to the problem his own intuition, experience, and knowledge of specialized techniques on the one hand and the tremendous computational power of the machine on the

other. As we shall see, it is possible for him to build a representation, in the computer, of those analytic tools he believes valuable for a particular problem or problem area. Without any necessity for learning conventional programming techniques, he is able, using only the concepts of classical mathematics, to create his own machine language, one tailor-made to his own needs. He can freely manipulate the elements of this language, in precisely the same fashion one composes mathematical techniques, and can easily modify them to incorporate the knowledge gained from their use in problem solving, so that his computing capability grows with his understanding of the problems.

We shall describe this "on-line" system from the point of view of a typical user rather than that of a "computer expert", by which we shall henceforth mean someone skilled in the art of programming, as opposed to the "user" whom we assume to be totally unversed in such matters. The programming principles and details will be the subject of a separate article. We shall only discuss the presently existing system, as it has been operating since August, 1962. While this will inevitably entail the mention of certain specific aspects of the particular computer used (AN/FSQ-27; RW-400), it should be kept firmly in mind, that while the detailed organizational choices were such as to take maximum advantage of the particular characteristics of this machine, the on-line techniques are in no way dependent upon

these characteristics. In the last chapter we sketch a method for using these on-line techniques with a standard operational computer center, a method consistent with the usual economic constraints on computer time.

In what follows, we restrict ourselves to the use of on-line techniques in the solution of mathematical and physical problems, this being the area of principal interest to us and the only one in which we have actual experience with an on-line system. We believe, however that the techniques can be extended to quite different areas of computer applications, a point to which we return in the last chapter. Meanwhile, we shall, in the interests of clarity, confine ourselves to a very specific description of the present system.

This work is an extension of an initial effort in which a particular problem, the energy gap integral equation of the Bardeen-Cooper-Schrieffer theory of superconductivity, was solved with an on-line approach[2]. However, in that work, which was carried out in the period July through December 1961, all of the subroutines for the problem were programmed in a conventional way. While the user was free to compose these elements in various ways using the control and display capabilities of the control console in solving the gap equation, he had no freedom to modify, on-line, the subroutines or create new ones, a freedom which is an essential characteristic of the present system. Thus, the earlier work comprised some aspects of items A and B, described below, but none of item C, the console programming.

## II. THE ON-LINE SYSTEM

At the outset, we should emphasize that each aspect of the design of such a system involves a number of choices. We shall describe here our own, with no representation that they are in every case the optimum ones; in fact, in some cases experience has indicated how some of these might be improved. Nonetheless, the resulting system operates in a very satisfactory manner.

Three principal features, independent but interacting, characterize the system:

### A. Functional Orientation

The programming structure is such that in the computer, as it appears to the user, functions (sets of 101 points) rather than individual numbers constitute the elements while the repertoire of "commands" consists of operations on functions (e.g., arithmetic, differential, and integral operations).

### B. Control and Display Capability

Central to the operation of the system is a control console having a number of push buttons or keys, which allow for user control of the computer, and two 17 inch CRT oscilloscopes (with line-drawing capability) which provide direct graphical representation of computational results. An 8 inch CRT with alphanumeric capability and a flexwriter provide numerical output when required.

### C. Console Programming

A simple procedure allows the user to construct, directly at the console, new subroutines, using as building blocks an initial

set of hand programmed[3] subroutines, plus any subroutines previously created by this "console programming"[4] procedure.

We shall now flesh out this skeletal description with further details. The keys of the control console are divided into three groups: 24 are used for function storage; 30 to designate operations on these functions; and 11 (the digits 0 through 9, $\oplus$ and $\ominus$ ) for the input of individual numbers[5]. Throughout we mean by a "function" a set of 101 points, i.e., 202 numbers, represented in the computer as 202 machine words, each word having 26 bits . (The choice of 100 intervals for the description of a function is one example of the arbitrary choices mentioned in the first paragraph. With fewer points one cannot adequately represent very much structure, while if 100 are insufficient one should probably use a different scale, or a different representation.) In addition to the 202 numbers, which all lie between -1 and 1, each function carries two scale factors (to base 2), one for abscissa values ($s_x$), the other for ordinates ($s_y$). The actual function values are thus the prcduct of the 101 mantissas $y_n$, $1 \leq n \leq 101$ and the common scale factor, $2^{s_y}$. For convenience, a block of 256 words is assigned to each function, the remaining 52 words being available for other labeling, for functional values (in the sense of Volterra), etc.

Because the computer module (CM) of the RW-400 has only 1024 words, functions are stored on an 80,000 word magnetic drum.

Half of the CM memory is used for two "function registers", called the C and D registers, each having a capacity of 256 words. They play a role for functions quite analogous to that which the accumulator in a computer plays for numbers: functions to be operated upon are loaded into the C and D register and the resulting function is eventually stored back on the drum.

Each of the 24 function storage keys addresses a particular section of the drum but this is of no concern to the user, who may think of the keys themselves as the storage locations. These keys initially carry some neutral labeling (e.g., the letters A through X) but as the user stores functions in them he relabels them (using any convenient nomenclature) to indicate the function stored there.

We can now describe some of the basic operator keys. LOAD and STORE bring any desired function from the drum into the D register or, conversely, store the contents of the D register into any specified function location. For example, pressing the LOAD key and then some function key, say R (or in a shorthand notation we shall employ henceforth, in which each word or symbol corresponds to the name of a particular operator or function key, LOAD R) brings the function stored in key R into the D register. Similarly, STORE F transfers whatever function may be in the D register to location F. In both cases, the words written (on the drum or in the CM memory) replace whatever was previously in that location. (The contents of the cells from which the information was taken are left unchanged so that immediately after LOAD A or STORE A both the D register and the A key contain the same function.)

The operator key J-GEN creates the identity function, $y = x$, $(-1 \leq x \leq 1)$ and puts it in the D register. The arithmetic keys (+, -, ·, ÷) cause the computer to carry out the indicated operation on the ordinates of two designated functions, assuming the abscissaes to be the same. For example, pushing the four keys

LOAD A + G

causes the computer to load whatever function is in location A into the D register; to load the function in location G into the C register; to add the y coordinates of the C and D registers, with differences, if any, in the y scale values properly taken into account; and finally to store the result in the y coordinates of the D register, leaving the x coordinates of the D register unchanged. If the user wishes the sum stored in some function storage location, say P, he then pushes STORE P. Alternatively, he can continue on with a series of arithmetic operations, all of which follow the same pattern. (Once the + button has been pushed, one may add as many functions as desired by simply pushing the + button again. This is true in general; once an operator button has been pushed that operation is continued as long as no other operator buttons have been pushed.)

Individual numbers can be put into the computer in a variety of ways. Since constant functions are sometimes required, we use them to represent also constant numbers, but this is by no means necessary. The procedure is simply: push the LOAD button; then type in the sign, followed by a mantissa less than 1, and any

desired power of 10, positive or negative. (For example, 11.56 is entered as ⊖.1156 ⊕ 02.) A constant function whose value is equal to this number is thereby loaded into the D register (i.e., the x values of the D register range as usual from -1 to +1 and the y values are all equal to the desired constant).

The DISPLAY key allows the user to see a graphical representation of any of the stored functions. DISPLAY A, for example, causes the computer to display on one of the 17 inch CRT scopes, the 101 points stored as functional values in location A, with adjacent points connected by straight line segments. Pressing the A key once more will erase the display curve from the scope (although not of course from the drum location where it is stored). Since only the mantissa values of a function are displayed on the CRT, we sometimes wish to check the scale of the whole function. This is done with the DISPLAY SCALE key, which causes the ordinate scale value, $s_y$, of the D register to be displayed on the alphanumeric scope. One thus has the capability of carrying out arithmetic and algebra on functions and examining the results graphically whenever desired.

The essential elements of calculus are provided by the $\Delta$ and $\Sigma$ keys. The former simply takes differences of adjacent ordinate values in the D register and leaves the result in the D register, e.g., $(y_n - y_{n-1})$ replaces $y_n$, $2 \leq n \leq 101$, with a special treatment at the lefthand end point (for example, the first difference computed on the basis of a second or third

order fit to the function values at that end replaces $y_1$). $\sum$ is just a cumulative sum of the ordinate values in the $\underline{D}$ register with the result left in the $\underline{D}$ register (0 replaces $y_1$

and $\left(\sum_{k=1}^{n-1} y_k\right)$ replaces $y_n$, $\quad 2 \leq n \leq 101$).

From these two keys it is easy to construct approximations of any desired accuracy to the derivative and (indefinite) integral operators.

At this point, the general nature of items A and B above should be clear. One has, in effect, a powerful, and exceedingly fancy, combination hand computer and plotting machine. Any desired function can be readily created in the computer (using power series, asymptotic series, etc.) and one can perform all of the operations of classical analysis upon them. Suppose, for example, one wants the sine of some function, f, which has been loaded into the $\underline{D}$ register and suppose further f is sufficiently small so that the first two terms of a power series

$$\sin f = f - \frac{f^3}{6} \tag{1}$$

suffice. Select two function keys, F and G, as "working space". The following keys would then be pushed:

STORE F · F F STORE G LOAD ⊖.166667 ⊕ 00 · G + F (2)

If f was initially in the $\underline{D}$ register, sin f, to the accuracy of Eq. (1), will now be there. In precisely similar fashion one could

obtain a representation of the sine function to any desired number of terms of the power series. However, it is clearly infeasible to go through this sequence of key pushes every time one wants the sine function. It is at this point that feature C, "console programming", comes in; like a giant lever (or a strong bootstrap) it provides an enormous multiplication of the capability available to the user.

Clearly, all that is required is that the computer be able to "remember" and suitably record a sequence of key pushes such as that given in the example above. Moreover, it should then, in some sense, attach this list of key pushes to some previously blank key, which thereby acquires significance. The procedure is simple: we select some key, hitherto blank, which we decide will be the SINE key, and so label it. We then "program" this key using the PROGRAM key in the following way. First push PROGRAM; then push the (hitherto blank) key which will henceforth be the SINE key; then push precisely the buttons listed in (2); finally, at the end, push the PROGRAM button again. The result is that the machine goes through a "dry run", i.e., executes the commands (2) in precisely the same fashion as if we had not pushed the PROGRAM button; examination (e.g., via the display capability) of the result of this dry run immediately provides a first check on the console program just created. In addition, however, the computer constructs a list of these key pushes, termed a "subroutine", and "inserts" it under the SINE key. If at any time in the future we

push the SINE key, the computer will go through precisely this sequence of operations[6]. Furthermore, we can in the same fashion program other keys, using as component keys not only the initial hand programmed ones (such as +, etc.) but also any keys which have been console programmed in the above fashion. These new keys can, in turn, be used as components of other console programs, and so on, to a depth limited only by the storage volume. (The present system allows for 256 such console programs but this could easily be expanded by several factors of 2.) In this way the operator creates his own subroutines, of arbitrary complexity, and pyramids these to achieve whatever computing capability he desires.

At this point it becomes difficult to describe adequately the generality and utility of the resultant system, just as it would be difficult to explain to a college freshman (in less than a few semesters) why algebra or calculus, whose basic principles can after all be rather concisely stated, is so useful. The on-line system has a structure very close to that of mathematics in its open-endedness, its generality and the constructive capability it affords the user. We shall therefore simply use the rest of this section to describe briefly the other hand programmed keys which are initially provided to every user when he begins work, and in the next section illustrate how this capability was used for one particular, fairly illustrative problem. A detailed characterization of all the hand programmed keys is given in Appendix A.

To begin with, the 30 operator keys physically present on the control console are by no means enough to encompass the initial hand programs plus the console programs needed in a typical problem. We therefore employ the concept of "overlays". To each overlay corresponds a set of meanings for the operator keys; changing the overlay changes the significance of all of these keys. The number of overlays is limited only by the size of the large volume storage in the computer system; in our case there are 32 overlays. One key common to every overlay is OVERLAY IN. The user changes overlays by simply pressing OVERLAY IN and then typing in, on the numerical keys, the number of the overlay he wishes to use. The 256 word program (which comprises the overlay from the programming point of view) is thereupon brought from the drum into the computer and all further key pushes will be interpreted by the computer in terms of that overlay until the operator makes a change of overlay. (In addition to the OVERLAY-IN and PROGRAM keys, five others, to be described later - REPEAT, OVERLAY-OUT, DISPLAY-OV-NUMBER, INSERT and DO - are common to all overlays, leaving a total of 24 x 32 = 768 keys in the present system, each of which can have a hand program or a console program.) The existence of multiple overlays modifies the console programming procedure slightly in that we must inform the computer not only which key is to be programmed but also which overlay we want that key to be on. The latter is accomplished by simply typing in the desired overlay number (on the numerical keys) immediately after

pushing the key being programmed: for example, PROGRAM SINE 10 followed by the key pushes (2) and then PROGRAM would attach the subroutine (2) to the indicated key of Overlay 10.

In a similar way, the total number of function storage keys available can be multiplied up from the 24 keys physically present to an extent again limited only by storage space. In the present system, we have 6 "banks" of these function keys, giving a total of 144 function storage locations. This too can be accomplished in many ways; at present, in place of the LOAD and STORE keys described above, we have in fact six LOAD and six STORE keys. Thus, $\text{LOAD}_{\text{I}}$ A will load into the D register whatever function is under key A on bank I; $\text{STORE}_{\text{VI}}$ F will store into key F of bank VI whatever function is in the D register, etc. (We use Roman numerals to label banks, Arabic to label overlays, thus minimizing a possible source of confusion.)

In typical operation, a user begins with an initial complement of hand programs and, working for a period of one to two hours[7], creates and checks (by observing the character of displayed curves, examining individual numerical values, running test cases, etc.) the console programs he needs. When his period of operation is finished, he pushes the SYSTEM DUMP button which stores the entire system (contents of the computers and of the drum) into a designated section of magnetic tape. When he next returns to the machine his system is loaded back from this tape and the computer is in precisely the same state as when he left. In the interim

another user comes to the machine, and loads his system from tape. All of the buttons, save for the initial core of hand programs, will typically be different for two users so that arguments concerning the value, efficiency or desirability of any particular console programming need never arise; each user makes his own choice, i.e., literally creates his own language.

When a user returns to the machine, SYSTEM LOAD (the inverse of SYSTEM DUMP), using his tape, restores the system (computer and drum) to precisely the state in which he left it, so that he can continue on, creating new console programs or, when he has built sufficient capability, attacking his problem. If, in the latter case, he immediately discovers a need to create new console programs or modify existing ones he is free to do so. (To reprogram a key he simply programs it as though it were blank; any previous program is simply buried.)

The SYSTEM LOAD and DUMP buttons are part of a "system" overlay which allows one to control the several components of the RW-400 system: to write out a block of data on (or read a block from) a tape unit, a buffer, the drum, etc.; aside from the tape operations, these are of interest principally to the computer expert rather than to the typical user, so we shall leave further details for the Appendix. (See Section A4, System Control Capabilities.)

The remaining hand programmed keys fall into three groups:

1. Mathematical Operations

These include first of all the arithmetic operations (on functions!) which have been mentioned already but require further comment. There are at least three ways of carrying out the function arithmetic: fixed point (with respect to the entire function), floating point (with respect to the entire function) or floating point for each point of the function. Since each has its own virtues, it is desirable to allow the user a free choice. Thus on Overlay 01 the arithmetic is done in a fixed point fashion. For example, when two functions are added, the y scales are compared and the smaller of the two is made equal to the larger one, the associated mantissa values being decreased (i.e., shifted to the right) enough times so that the functional values (mantissa plus scale) remain unchanged; the mantissa y values are then simply added together. If at some point the sum of these happens to be greater than 1, there will be an overflow. This is readily apparent if the sum is displayed, but it may happen in the course of a console program (unless one has correctly anticipated all scaling aspects of the problem) and can then be a considerable nuisance. Similar comments apply to divide, which will overflow at any points where the mantissa of the numerator exceeds the mantissa of the denominator. A second arithmetic overlay, 02, provides protection against such overflows by first floating and then contracting both

summands before addition. In division, the numerator and denominator are first floated and then the numerator is contracted enough times to prevent overflow at any point, if no more than 12 contractions are required, but no more than 12 are made in any case. An Overlay 03,in which the arithmetic is done on a floating point basis for each individual point of the functions, has recently been incorporated into the system but we have not yet sufficient experience to compare it with the other two. Of the latter, Overlay 02 is generally the more convenient, but in special circumstances (larger range of variation within a single function) can lead to more loss of accuracy than would result from the careful use of Overlay 01.

In addition, we have the following: EXPAND y decreases $s_y$ by 1 and doubles all the mantissas of the D register; CONTRACT y is its converse. (They are needed in conjunction with the arithmetic on Overlay 01 and also allow examination (on the CRT) of small amplitude structure of a curve, display of curves at common scale, etc.) FLOAT MANTISSA does EXPAND y as many times as possible without causing overflow at any point. EVALUATE picks out the value of the function in the D register at the x coordinate closest to any designated value. REFLECT interchanges the x and y coordinates of the D register; SUBSTITUTE puts the y coordinates of the C register in place of the x coordinates of the D register. (Using REFLECT and SUBSTITUTE one can create, from the real function arithmetic hand programs, console programs for complex function arithmetic. Using REFLECT and EVALUATE one can find extrema of

a function.) δ-FUNCTION creates in the D register a function which is 1 at any desired point and zero elsewhere. INTEGRAL-TRANSFORM transforms the function f in the D register, using a kernel K(x, x') previously stored on tape as 101 functions of x', and leaves the result, $\tilde{f}(x) = \int dx' \, K(x, x') \, f(x')$, in the x coordinates of the D register. EXPONENTIAL, SINE and COSINE operate on the function contained in the D register, leaving the result in the D register. LEFT-SHIFT and RIGHT-SHIFT perform the indicated operations on the y coordinates of the D register. RELATIVE INTERPOLATE accepts graphical point inputs (via user-controlled crosshairs on the CRT) and modifies the function in the D register so that it passes through these data points, preserving its initial shape between data points.

2. Aids to Console Programming

These include besides the PROGRAM key already described, also REPEAT, a key which allows any console program keys to be repeated any desired number of times, and two keys (TALLY and COMPARE) which provide the capability for branching within a console program.

3. Display and Output Keys

These provide the capability to display on the alphanumeric scope the number of the overlay currently in the computer; to erase all curves from the CRT; to display (on the alphanumeric scope) the binary scale of the function in the D register, as well as the value of the first point of that function; to input

individual points graphically, using a movable crosshair; to print a hard copy of any desired curve on the flexwriter; to produce English language labels for kernels stored on tape, dumps stored on tape, or curves printed out on the flexwriter; to display curves on either of the two 17 inch CRT's; to use other display formats (dots along, crosses, circles, etc.) as well as the usual display of line segments.

In addition to these, there are Aids for the Hand Programmer involving the convenient input of machine words from the console, the display of sections of memory in machine language, etc., These are described in the Appendix, together with more detailed specification of all the keys already mentioned.

In a class by itself is the SECOND-COMPUTER key which at first glance seems highly specific to the RW-400 and yet really provides an excellent illustration of how to set up an on-line system for an arbitrary computer. In the RW-400 system, there are two identical computer modules, CM-1 and CM-2. The control console is tied directly to CM-1 and this is the only one used in all of the operations described so far. Suppose however that operator key [K] on Overlay 10 is a rather long program, requiring several minutes or more to run. It is then efficient to use the SECOND-COMPUTER key, as follows: press SECOND-COMPUTER, press [K], and type in the number (in this case 10) of the overlay on which [K] is located. CM-2 then performs this program, taking the subroutines and curves needed from the drum in the same way that CM-1 would do.

While this is going on, however, the user is free to operate in the normal fashion with the control console and CM-1, doing computations; examining, if he likes, intermediate results as they are generated by CM-2; preparing new programs; setting up material for the next case; etc. In the last chapter we will explain how this serves as a model for an on-line system using a conventional, large central computer.

## AN ILLUSTRATIVE PROBLEM

As an illustration of the use of the on-line system, we describe briefly one problem we have studied, a linear integral equation for a complex function of a real variable. While a single problem can no more exhibit the power and generality of the on-line system than any one application of, say, calculus, can illustrate the utility of classical analysis, we include it to show the ease with which rather sophisticated mathematical techniques can be employed in a system of this sort.

We present the problem as a mathematical one, essentially suppressing the context of physics from which it arose; outline the mathematical methods used; indicate some of the principal console programs generated to implement these methods; and show a few sample results. We can state, but not easily illustrate, one essential point: the method of solution finally adopted was itself the result of experimentation with the on-line system. Several approaches were tried; some quickly proved themselves unsuitable, but as we learned more about the nature of the solutions, we were able to develop satisfactory methods for obtaining them. Thus, quite apart from questions of mathematical convergence (e.g., of an iteration process), one sees a convergence in a kind of space of mathematical techniques.

A study of the electrostatic wave fluctuations in an electron-ion plasma subjected to an external electric field leads to the following integral equation[8] for the fluctuation electric field, of wave number k, as a function of time:

$$E(t) + \int_0^t dt' \left\{ K_e(t-t') \exp i \left[ \phi(t) - \phi(t') \right] + \right.$$

$$\left. \delta\, K_i(t-t') \exp i\delta \left[ \phi(t') - \phi(t) \right] \right\} E(t') = I(t), \qquad (3)$$

$$0 \leq t \leq T$$

where

$$K_e(t) = te^{-k^2t^2/4} \qquad K_i(t) = te^{-\delta k^2 t^2/4}$$

$$\phi(t) = \mathcal{E}\, t^2/2 + ut \qquad \delta = 1/1836$$

and $I(t)$ is given. (We have chosen units in which the electron thermal speed $(2T/m)^{1/2}$ and the plasma frequency, $(4\pi ne^2/m)^{1/2}$, are unity.) We shall say no more here about the physics of the problem since this is discussed elsewhere[9], and only sketch the on-line techniques used to solve it.

Using an operator notation for the integral transforms in (3),

$$\underset{\sim}{K}_e \cdot E \equiv \int_0^t dt'\, K_e(t-t')\, E(t'), \text{ etc.} \qquad (4)$$

we can write (3) as

$$E + e^{i\phi}\underset{\sim}{K}_e \cdot (e^{-i\phi}E) + \delta e^{-i\delta\phi}\underset{\sim}{K}_i \cdot e^{i\delta\phi}E) = I \qquad (5)$$

Over the time interval of interest ($T \lesssim 10\pi$) the norm of the first operator in (5) is so large, for $k \leq 1$, that an attempt at direct iteration proved useless. (As can be seen from the soluble special case, $k = \delta = \phi = 0$, this corresponds to computing

sin t by a power series on the interval $0 \leq t \leq T$.) However, the transformation

$$F = e^{-i\phi} E \tag{6}$$

gives an integral equation for F,

$$F + \underset{\sim}{K}_e \cdot F + \delta e^{-i\psi} K_i(e^{i\psi} F) = J \equiv I e^{i\phi} \qquad \psi \equiv (1+\delta)\phi \tag{7}$$

which can be solved by iterating only the last of the terms on the left hand side. The equation

$$F + \underset{\sim}{K}_e \cdot F = A \tag{8}$$

has the solution

$$F = A - \underset{\sim}{L}_e \cdot A \tag{9}$$

where $\underset{\sim}{L}_e$ is, like $\underset{\sim}{K}_e$, a translate type integral operator and hence specified by a single function $L_e$

$$\left[\text{i.e., } \underset{\sim}{L}_e \cdot A \equiv \int_0^t dt' \, L_e(t-t') \, A(t')\right]$$

which must obey an equation like (8) with A replaced by $K_e$:

$$L_e + \underset{\sim}{K}_e \cdot L_e = K_e \tag{10}$$

Having once found (for given k) the function $L_e$, we write (7) as

$$F = (1 - \underset{\sim}{L}_e) \cdot \left[J - \delta e^{-i\psi} \underset{\sim}{K}_i \cdot (e^{i\psi} F)\right] \tag{11}$$

and solve it by iteration

$$F_{n+1} = (1 - \underset{\sim}{L}_e) \cdot \left[J - \delta e^{-i\psi} \underset{\sim}{K}_i \cdot (e^{i\psi} F_n)\right] \tag{12}$$

With a reasonable initial guess, e.g., $F_0 = J$, we find that this converges splendidly (three iterations). From F we compute, finally, $E = e^{i\phi}F$.

The first step is to find $L_e$ from (10). For the reasons noted above, straight iteration is ruled out. While (10) can indeed be solved with Laplace transforms, the transform of $L_e$ involves the error function of complex argument[9] and hence is difficult to invert. Instead, we take advantage of the fact that problems which are "adjacent" in a mathematical sense are, within the on-line system, adjacent also in a computational sense. If $K_e$ is replaced by

$$R = N^2 te^{-at}, \tag{13}$$

then the inverse kernel function, $L_R$, satisfying

$$L_R + \underset{\sim}{R} \cdot L_R = R \tag{14}$$

is simply

$$L_R = Ne^{-at} \sin Nt. \tag{15}$$

We therefore write (10) in the form

$$L_e + \underset{\sim}{R} \cdot L_e = K_e + \underset{\sim}{D} \cdot L_e \tag{16}$$

$$D = R - K \tag{17}$$

and choose N and a so as to make the norm of D small (e.g., $a = k$, $N = 2$), thus permitting an iterative solution,

$$L_e^{(n+1)} = (1 - \underset{\sim}{L_R}) \cdot (K_e + \underset{\sim}{D} \cdot L_e^{(n)}) \tag{18}$$

This converges nicely (three or four iterations) to yield a result which will differ from the exact solution of (10) only in consequence of the approximation inherent in numerical methods. However, we can exploit the linearity of (10) to obtain a more accurate solution as follows. Let L be the result obtained by iterating (18) until it has converged. The error in L is measured by the size of

$$P \equiv K_e - L - \underset{\sim}{K}_e \cdot L \tag{19}$$

and the difference $\eta = L_e - L$ satisfies

$$\eta + \underset{\sim}{K}_e \cdot \eta = P \tag{20}$$

or equivalently

$$\eta = (1 - \underset{\sim}{L}_R) \cdot (P + \underset{\sim}{D} \cdot \eta), \tag{21}$$

i.e., an equation identical with (18) save for the inhomogeneous term. If L is determined from (18) up to a percentage error of order $\epsilon$, we can find $\eta$ from (21), also with a percentage error of order $\epsilon$, and hence get an approximation, $L + \eta$, to $L_e$ which has an error of order $\epsilon^2$. In a similar fashion we can find a correction to $\eta$, and so forth.

We now indicate how the on-line system was used to solve (7) by these methods. To begin with, certain function keys are assigned to the constant parameters of the problem and to the principal independent and dependent variables as shown in Table I. Locations for constant functions which one finds it convenient to have on hand are assigned as the need arises. (The notation in Table I

| | | | |
|---|---|---|---|
| $\mathcal{E}$ | k | u | T |
| $\delta$ | N | a | $\Delta t$ |
| t | $K_e$ | $K_i$ | R |
| $L_R$ | $L_e$ | 0 | $\frac{1}{2}$ |
| L | L' | L'' | L''' |
| f | $\tilde{f}$ | kernel source | working space |

Table I

Assignment of function storage spaces (keys) on Bank I for the plasma oscillation problem. Significance of the symbols is given in Eqs. (3) through (23).

is the same as in Eqs. (3) through (23); the meaning of other symbols will be explained below.) Once assigned, the labels on the function keys are used in referring to these keys rather than the neutral ones (A, B, ....X) of the preceding chapter.

Operator keys are then created, using the console programming procedure, some of the principal ones being as follows:

$[t]$ This creates the function $t = T(x+1)/2$ (assuming that the desired value of T has been previously stored in the T key of bank I) and stores it in t on bank I. It also computes $\Delta t$ and stores it in $\Delta t$. As an illustration of console programming, we list the key pushes made in programming this key[10], which we suppose is to be on, say, overlay 10:

PROGRAM $[t]$ 10 OVERLAY-IN 02 J-GEN · 1/2

+ 1/2 · T STORE t $\Delta$ STORE $\Delta$t PROGRAM (22)

INITIAL SET-UP This simply displays on the alphanumeric scope the names of the constant parameters ($\mathcal{E}$, T, k, $\delta$) and, next to each, the value presently stored for it on bank I. If the user wishes to change any of these he can, of course, do so before running the problem. This program also stores the various constants indicated in Table I and finally pushes the $[t]$ key. Thus one knows that everything is in order for the start of a calculation.

$[K_e]$ This simply computes the kernel function $K_e(t)$ and stores it on bank I.

$[R]$ This computes and stores the function, R(t) defined by (13), using whatever values the user has stored in N and a on bank I.

$[L_R]$ This computes and stores the function $L_R(t)$ defined by (15). It, for example, was programmed by:

PROGRAM $L_R$ 10 OVERLAY-IN 02 LOAD t · N SINE STORE $L_R$ LOAD -1 · t a EXP · N $L_R$ STORE $L_R$ PROGRAM.

(Note that in this we have used the $L_R$ key as a temporary working space to store one factor of the final answer.)

We frequently need to generate, on tape, the 101 functions which comprise one of our translate kernels. To produce this capability, we first program a KERNEL-GENERATE-AUXILIARY (KGA) key as follows:

PROGRAM KGA 10 OVERLAY-IN 02 LOAD KERNEL-SOURCE TAPE-WRITE LEFT-SHIFT STORE KERNEL-SOURCE OVERLAY-IN 10 PROGRAM.

This subroutine takes whatever function is in the kernel-source space on bank I, writes it out on tape, left shifts it,($y_{n+1}$ replaces $y_n$) and stores it back in the kernel-source space. We end it by calling in the overlay (10) on which KGA has been programmed in order that it be a repeatable key. The key which will actually produce the kernel on tape is then made by simply repeating the KGA key, i.e., we make a KERNEL-GEN key as follows:

PROGRAM KERNEL-GEN 10 OVERLAY-IN 10 REPEAT KGA 101 PROGRAM.

(Repeat $[K]$ followed by a number, n, causes key $[K]$ to be repeated n times.)

It is clearly now a simple matter to make, for any desired value of k, the various functions and kernels needed for (18).

Since we will be taking many integral transforms, it proves convenient to incorporate the hand-programmed integral transform key (which produces in the x-coordinates of the D register the transform of the function in the y-coordinates of the D register) into a simple console program which will produce in the $\tilde{f}$ space of bank I the transform of whatever function has been stored in f on bank I. We designate this as INT-TRANS and, using it, program a new key, ITERATE-$L_e$ which does one pass of (18) as follows. Assume that the kernel D has been stored on tape and, following it, the kernel $L_R$; that the tape is positioned to the beginning of the D kernel; and that some initial guess, or the result of a previous iteration is in $L_e$ on bank I. We then do

PROGRAM ITERATE-$L_e$ 10 OVERLAY-IN 02 LOAD $L_e$ STORE f OVERLAY-IN 10
INT-TRANS OVERLAY-IN 02 LOAD $\tilde{f}$ + $K_e$ STORE f OVERLAY-IN 10
INT-TRANS OVERLAY-IN 02 $LOAD_I$ f - $\tilde{f}$ $STORE_I$ $L_e$ REWIND-TAPE (23)
OVERLAY-IN 10 PROGRAM

Although the program (23) is adequate, we add to it certain display and storage features which increase the convenience of operation. That is, after checking (with simple examples, special cases, etc.) the correctness of (23), we program another key, $\lceil L_e \rceil$ which first pushes the ITERATE-$L_e$ key (23) and then goes on to store the resultant $L_e$ in key L, having first moved the contents of L'' into L''', L' into L'', and L into L'. Thus as the new key $\lceil L_e \rceil$ is repeated, we are able to examine the results of the most recent four passes (and could, of course, save even earlier ones if desired, by using one of the other banks). In

addition, the new key erases the scope and then displays on it the contents of L' (dotted) and the contents of L (usual dot-plus line display). Thus, each time the key is pushed the user sees, as soon as the pass has been completed, both the new result and, for comparison, the previous one, so that he can judge the convergence characteristics of the iteration process (18). (One could as well display the ratio or difference of the old and new curves, etc.)

The reader who has followed the details of the last few paragraphs can supply those omitted from what follows. Having created the programs needed for (18), we can use them also for (21) and, by repeating the correction process, obtain a very accurate $L_e$. From it we make an $\underset{\sim}{L}_e$ kernel (using KERNEL-GEN) and also the $\underset{\sim}{K}_i$ kernel and are then in a position to solve (12), i.e., to make a key which will do one iteration of (12). The only new complication lies in the complex character of F, but this causes no real difficulty. We simply write out on tape two copies of $\underset{\sim}{K}_i$ kernel, followed by two of $\underset{\sim}{L}_e$. The ITERATE-F key then multiplies F by $e^{i\psi}$, uses the INT-TRANS key to transform the real part of the product with $\underset{\sim}{K}_i$, stores that in some working-space function key, transforms the imaginary part with $\underset{\sim}{K}_i$, combines the results into a single complex function, multiplies this by $\delta e^{-i\psi}$, subtracts that from J, transforms the real part with $\underset{\sim}{L}_e$, then the imaginary part, etc.

This requires, of course, that one create also keys which produce $e^{\mp i\psi}$ (used only after a change of $\mathcal{E}$ or u) and keys which give complex arithmetic capability. Using REFLECT and SUBSTITUTE, one can easily program, for example, a COMPOSE key (which, given two real functions, $f_R(t)$ and $f_I(t)$, in two standard locations composes them into a single complex function $f=(f_R, f_I)$ with the parameter t eliminated) and a DECOMPOSE key which is its inverse. For example, designate 3 keys as $f_R$, $f_I$, f and then make COMPOSE by

PROGRAM COMPOSE 10 OVERLAY-IN 02 · $f_R$ LOAD $f_I$

SUBSTITUTE STORE f PROGRAM

(We use · $f_R$ as a way of loading $f_R$ into the C register.)

Similarly we have

PROGRAM DECOMPOSE 10 OVERLAY-IN 02 LOAD 0 + f STORE $f_I$

LOAD f REFLECT STORE $f_R$ LOAD 0 + $f_R$ STORE $f_R$ PROGRAM

(LOAD 0 + $f_R$ STORE $f_R$ is just a way of restoring standard x coordinates to $f_R$ so that it will look normal when displayed.) From these, it is then a simple matter to make the keys for complex function arithmetic.

Using the ITERATE-F key, and the $L_e$ kernels generated by the procedure described above, it is an easy matter to obtain solutions of (3) for a variety of values of the parameters k, u and $\mathcal{E}$. As we see from Figure 2 the kernel $L_e$, which is a sine wave for k = 0, is increasingly damped with increasing k. (Having computed $L_e$ one can compare it with the result obtained by keeping only the least damped pole of the Laplace transform

of $L_e$ when inverting the latter by contour integration[9]; as shown in Figure 2, the agreement is fairly good save near t = 0.) Understanding the somewhat exotic curves which result is assisted by comparing them with analytically soluble problems, e.g., those obtained by omitting the $\underline{K}_1$ operator in Eq. (3) or setting $\mathcal{E}$ equal to 0. Some typical results are shown in Figure 3 through 8 for the case I(t) = 1. An analysis of the results and a discussion of their significance is given elsewhere[9].

DISCUSSION

The on-line system we have described is specific both as regards the computer used and the area of mathematics emphasized (classical analysis), the choice of the computer being a consequence of its availability, while the selection of problem areas was dictated by the research interests of the participants. On the basis of the experience gained in the design and operation (since July, 1962) of this particular system, the extension of these on-line techniques to other computers and to other areas of application appears rather straightforward.

We first outline a system which would be suitable for a conventional, large central computer and which would permit an operation identical, from the user's point of view, with that we have described here. Besides the central computer itself, one needs a large volume storage element, such as a disc file, and a small satellite computer, one with a memory of the order of 8,000 to 10,000 words and a 5 to 10 microsecond cycle time. As input/output equipment, the satellite computer would have two electric typewriters, whose keys take the place of the control console keys, and two CRT display scopes, each capable of displaying of the order of 1000 points furnished by the satellite computer, and connecting pairs of these with line segments when desired.

The operation parallels that of the present system when the SECOND COMPUTER key is used, the control console and the

first computer module of the RW-400 being replaced by the satellite computer plus its input/output equipment; the drum (where curves and subroutines are stored) being replaced by the disc file; and the second RW-400 computer module being replaced by the (larger and far more rapid) central computer. The satellite computer is used to compose and check console programs and for all trivial computing: examination and comparison of curves, formation of ratios and differences, simple test cases, etc. Only when the user has progressed to a point of having a substantial computational task which he wishes performed, is the central computer involved. He simply presses the CENTRAL COMPUTER key and then any of the keys he has previously console programmed (with the satellite computer). The CENTRAL COMPUTER is not interrupted, but when it finishes the task on which it is presently engaged and returns to its own control system for a next assignment, it is directed to take from the disc file the satellite's request, carry it out and return the results to the disc file. The central computer then proceeds to other work while the user examines the results, perhaps modifies his program or decides on a next case. The central computer is brought in only for significant computational tasks and never waits for the user. The user may occasionally have to wait a short time for the central computer[11], but since the tasks he gives it are only those requiring a considerable amount of computation, this is not unreasonable.

In a sense, the satellite computer functions as a kind of informational impedance matching device between the man and the large central computer. Taken by themselves, these are mismatched with respect to both operations per second and dollars per hour. However, the satellite computer is economically matched to the man (i.e., rents for a figure comparable to his salary) and at the same time is sufficiently well matched to the central computer in terms of data transfer so as to be consistent with the economic constraints concerning the latter's use. Of course, many variants of this basic scheme are possible, some more suited to a particular computer center than others. Because our experience indicates that it is convenient to have of the order of 50 to 60 keys, we specify two typewriter keyboards, but in principle the necessary control capability, including that required for console programming, could be provided with far fewer keys. (Ten, representing the digits 0 through 9, plus one more ___ to, so to speak, change overlays ___ is probably the minimum required to provide a reasonable degree of operational comfort.) Because the simultaneous display of many curves on a single CRT scope gets quite confusing, it is very convenient to have two scopes, particularly for problems where one wishes to examine a mapping from one plane to another. One scope might be sacrificed, but we would argue strongly against the elimination of both, having found the rapid feedback of information in graphical form to be a tremendous asset in studying the structure of a problem and of the tools one creates, in the

form of console programs, to solve it, not to mention its value in checking and trouble shooting the latter. In any case, the effective implementation of such a system will share some of the problems inherent in any time-sharing arrangement[12].

We consider briefly the generalization of on-line techniques to other problem areas. The emphasis on functional orientation is particularly important for non-local problems but it is straightforward to include also a capability for dealing with individual numbers, something which would be useful, for instance, in solving differential or difference equations. This requires only an overlay (04, say) which interprets the function keys as single numbers, i.e., allows the function keys to address individual cells of the computer memory rather than function storage blocks on the drum, the arithmetic on Overlay 04 being just the conventional single number arithmetic of the computer itself[13]. Console programming would allow the composition of operations on this overlay in the usual fashion.

The extension to areas of mathematics other than classical analysis also seems feasible. To handle matrix problems, for example, one would replace the functional format by one in which matrices could be stored in the "function keys", with the basic operators being now those of matrix arithmetic rather than function arithmetic. For an algebra machine or a logic machine, the basic, hand programmed keys would correspond to the fundamental operations of these disciplines, but at present this

is still somewhat speculative. In each case, the general organizational scheme of the present system, including the control and console programming aspects, would be preserved, and only those parts (actually a small fraction) of the programming associated with the functional orientation and with the graphical displays would be altered. While this is true also of other areas of computer application (e.g., those involving information processing rather than mathematics), the identification of the basic operations from which all others can be compounded by console programming appears far more difficult, there being no analog for the experience accumulated in the physical and mathematical sciences during the past 300 years.

We turn now to the system as it presently exists. We note that much of its power derives from the fact that substitution can be carried out at several levels: substitution of numbers, of functions and of programs. Substitution of different parameter values is carried out by simply writing the console programs with the parameters in question represented by certain function keys; one then has only to insert the desired constant functions into these keys before running a program. The capability for functional substitution is provided by the REFLECT and SUBSTITUTE keys. Given two functions u(x) in the C register and v(x) in the D register, the SUBSTITUTE key produces in the D register the function v(u). When displayed,

this will be a curve in the (u,v) plane. Conversely, given such a curve, v(u), we can (as illustrated in the preceding chapter) easily obtain the parameterized curves u(x) and v(x).

Most important perhaps is the possibility of substitution at the program level. Suppose that we wish to make a change in a console programmed key [K] which is one of the components of another key [L], [L] in turn being a component of still a third key, [M]. If we wish to substitute a new console program for the one presently under [K], we simply program [K] in the same way as one does with a blank key; the program formerly associated with [K] will be buried. Alternatively, we may find that the console program associated with [K] is so basic and takes so long to run that it should be replaced with a hand program. (For this replacement the "user" must get the help of a "computer expert".) In either case, the program associated with key [M] will run precisely as before, save for the desired modification in [K], for the program in [M] recognizes [K] only as a key push, regardless of the significance of the subroutine it calls in.

One thus has the ability to manipulate console programs with approximately the same freedom as one juggles the mathematical operations which they represent, a feature not present in conventional programming languages. As a result, problems which are adjacent in the mathematical sense become so computationally as well; one can proceed from the simple to the more complicated, always building upon the results of what one has learned, without

the necessity for redoing all of the programming as new pieces are added or old ones are modified.

While we have characterized the "user" of the on-line system as a scientist unversed in conventional programming methods, it is clear that the creation of console programs involves the very essence of programming, albeit with most of the drudgery eliminated, and that "users" would benefit from the advice of someone familiar with programming. Indeed, operation of the on-line system involves two activities which at first sight appear separable: a) the creation of those console programs needed for a problem; and b) the use of these in its solution. Why not let someone we may call a "console programmer" (since his qualifications will differ somewhat from those appropriate to programmers in the standard meaning of the word) take care of a), the "user" being involved only with b)? The point is just that a) and b) are in fact strongly coupled; as soon as one starts to use b) he typically finds that some changes or additions are needed and he must revert back to a). If the user does not actually do a) himself, he must certainly work very closely with the "console programmer" who does, in order that he thoroughly understand the significance of the keys in his system. Moreover, unless the user is familiar, from hand computation or other experience, with numerical methods, a mathematician skilled in such matters had better be available for consultation; for the privilege of having direct access to a

computer, the user must pay the price of being exposed also to questions of scaling, error accumulation and all the other technical problems which are of course involved in any computational work but which are seen dimly, if at all, by the user when, as in most conventional organizations, he is insulated from the computer by several layers of intermediaries.

In conclusion, we should emphasize that there will be many computer applications for which these on-line techniques will be of little or no value. If one thoroughly understands the structure of a problem and knows a method of solution which is certain to work, then the experimentation and feedback characteristic of the on-line system are unnecessary. Indeed, such problems are handled very nicely by computer centers as presently constituted. It appears, however, that for problems whose structure is not clear, either a priori or on the basis of previous experience, and for which successful solution techniques need to be developed, an on-line system which allows the technical intuition of the user to play a central role in the solution process can be of considerable value. In this system, the user has a direct and convenient access to the computer, a fast response for computations which are essentially trivial, and a graphical representation of information where appropriate. He can build programs consisting of his own constructs within his own field, combine these in any desired way, and, if appropriate, make a

trial-and-error study of the various features of his problem. Indeed, the interplay of the structural elements is often more important than the solution itself in terms of the information desired in a research problem. Since he has control over the transformations, operators and other mathematical objects involved in his problem, he is able to get hold of the pieces and study the ingredients from the point of view of validity as well as from the point of view of structure. When he has found successful methods, he can combine these into an operating program without the necessity of reprogramming. Finally, from the bulk data available after solving a problem, he is able to select only that which he really desires, either as hard copy, numerical output or in the form of pictures of curves displayed on the CRT.

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for research problems in their own fields, notwithstanding its then somewhat raw and rough-edged character, thus contributing greatly to its present state of development and to our understanding of the user's needs and desires in an on-line system.

## APPENDIX - DESCRIPTION OF BASIC SUBROUTINES FOR AN ON-LINE SYSTEM

The initial hand programmed keys which at present comprise the basic system from which every user starts may be divided into five categories, save for the especially significant SECOND COMPUTER key, which stands by itself:

1. Mathematical operations.

2. Capabilities which provide assistance in the creation of console programs.

3. Programs having to do with displays or with other input/output aspects.

4. Operations involved in management of the computer system.

5. Conveniences for the computer expert who may be concerned with hand programming.

Many other items could be added to the list which follows and some of those given here could be omitted. While our set is neither exhaustive nor minimal, it has proved to be extremely convenient. Names of operator keys are in capital letters; headings not capitalized refer to groups of keys so closely related that to save space we have not listed them separately. In the description of keys we shall, in the interest of simplicity, ignore the multiplicity of function banks[14].

A1. Mathematical Keys

LOAD  $LOAD_I$ A brings the function in key A of bank I into the D register. (It also remains in A on bank I.) Similarly for $LOAD_{II}$, ---$LOAD_{VI}$.

STORE  $STORE_I$ puts the function in the D register into key A on bank I, leaving it also in the D register. Similarly for $STORE_{II}$ ---$STORE_{VI}$.

FLOAT-MANTISSA  The y values of the D register are shifted left as many times as possible without causing any one of them to overflow, and the scale value $s_y$ is adjusted appropriately. The x values of the D register are unchanged.

+  On Overlay 01, + A puts the function stored in key A into the C register, and then compares the y scales of the C and D registers. If the scales are equal, the y values are added together and left in the D register. If the y scales are unequal, the function with the smaller scale is contracted until the scales are equal and the addition is then performed. The x coordinates of the D register are unchanged. If the same operation is performed on Overlay 02, both functions are floated, each is contracted once, and the addition is then carried out as on Overlay 01.

·  On Overlay 01, · A loads the function stored in key A into the C register, multiplies its y values by those of the D register, adds the scales, and leaves the result in the D register. In the same operation on Overlay 02, each function is first floated.

$-$ Subtraction is performed in the same fashion as addition.

$\div$ On Overlay 01, $\div$ B loads the function stored in key B into the C register, divides the y values in the D register by those in the C register, subtracts the scale values, and leaves the result in the D register. When the same operation is performed on Overlay 02, each function is first floated and the numerator is then contracted enough times to prevent overflow at any point unless this requires more than 12 contractions, in which case the numerator is simply contracted 12 times.

$\sqrt{\phantom{x}}$ $\sqrt{\phantom{x}}$ takes the square root of the function stored in the D register and leaves the result in the D register.

LEFT-SHIFT The y values of the D register are shifted one place to the left: $y_{n+1}$ replaces $y_n$, $1 \leq n \leq 100$, and $y_{101}$ is left unchanged.

RIGHT-SHIFT The y values of the D register are shifted one place to the right: $y_{n-1}$ replaces $y_n$, $2 \leq n \leq 101$, and $y_1$ is left unchanged.

EVALUATE This allows one to evaluate the function in the D register at the value of the x coordinate nearest to any selected number, previously stored as a constant function in one of the function storage spaces. The operation is as follows: EVALUATE B loads the function stored in B into the C register and subtracts the y coordinates of the C register from the x coordinates of the

D register. The y value in the D register corresponding to the smallest of these differences is selected and all y coordinates of the D register are set equal to that value.

EXPAND y The y values of the D register are multiplied by two (shifted one place to the left) and the scale value $s_y$ is reduced by 1.

CONTRACT y The y values of the D register are multiplied by 1/2 (shifted right one place) and the scale value $s_y$ is increased by 1.

Both EXPAND and CONTRACT leave the numerical value of the function invariant since a change in scale appropriately compensates the alteration in mantissa values. However, since only the latter are displayed, the appearance of the function on the CRT is altered. One can use EXPAND to examine in detail the small amplitude structure of a curve, letting the other parts overflow being careful, of course, to retain the original representation of the function in another storage spot ; it thus complements FLOAT-MANTISSA. If one uses Overlay 01 (fixed point arithmetic) CONTRACT is necessary in order to avoid overflow in addition, subtraction. Finally, both EXPAND and CONTRACT are useful in bringing curves to a common scale for visual comparison.

δ FUNCTION This creates a Kronecker-δ type function, i.e., one which has the value 1 at one point and zero everywhere else. To create the function $\delta_a = \delta(x - a)$, load the number a into the D register then push the δ function button. The desired function

then appears in the D register, i.e., all of the y coordinates in the D register are made 0, save the one corresponding to the value of x nearest to (or equal to) a, and it is set equal to 1.

EXPONENTIAL The exponential of the function in the D register is computed and the result is left in the D register.

SINE-COSINE The sine and cosine of the function in the D register are computed. The sine is put in place of the y values of the D register; the cosine is put in place of the x values of the D register. (This may alternatively be considered as a complex exponential $e^{if}$, where f is the function in the D register.)

J-GEN The identity function, $y = x$, $-1 \leq x \leq 1$ is put in the D register.

REFLECT The x and y values of the D register are interchanged, as are also the scale values, $s_x$ and $s_y$.

SUBSTITUTE The y coordinates of the C register replace the x coordinates of the D register and similarly for the scale values. This permits, for instance, the cross plotting of two dependent variables which are functions of the same independent variable. Together with REFLECT, it allows one easily to create console programs for complex-valued functions of complex arguments using only real function hand programs (i.e., those described in the foregoing part of this section).

INTEGRAL TRANSFORM The integral transform of the function

$$\tilde{f}(x) = \int_a^b dx'\ K(x, x')\ f(x')$$

f stored in the D register is computed, using a kernel $K(x, x')$ which has been stored out on magnetic tape in the form of 101 functions of x', one for each value of x. Assuming that the tape has been correctly positioned and that f is in the D register, we simply push the INTEGRAL TRANSFORM key. The first of the 101 functions, i.e., $K(a, x')$, is then read into the C register and multiplied by the function in the D register. The definite integral is computed and the resulting number is stored in the first x coordinate of the D register. The next function, i.e., $K(a + \epsilon, x')$, $\epsilon = (b - a)/100$, is then read from tape into the C register and the process repeated, the result being stored as the second x value of the D register. At the completion of the operation, which requires 7 seconds, f is still contained in the y coordinates and $\tilde{f}$ is in the x coordinates of the D register. To transform the latter into standard form one could, for example: REFLECT STORE A, LOAD 0 + A (the addition to 0 being one means of restoring the x coordinates of the D register to the canonical form used for the displays).

RELATIVE-INTERPOLATE This uses individual data points, put in with the graphical input techniques described below (Section A3), to modify the function, say f, which has been loaded into the D register. If $P_a$ and $P_b$ are two of the data points, the

program first finds the two points, $\bar{P}_a$ and $\bar{P}_b$, of f whose x coordinates match those of $P_a$ and $P_b$. If L is the straight line $P_aP_b$ and $\bar{L}$ is the line $\bar{P}_a\bar{P}_b$, the function f is replaced by $(f - \bar{L} + L)$ for $x_a \leq x \leq x_b$. The function is left unchanged between x = -1 and the smallest of the $x_a$. (Before f is loaded into the D register, it should be displayed on the CRT scope to serve as a guide for placing the data points on the screen with the crosshair.)

A2. Aids to Console Programming

PROGRAM Press PROGRAM; then press the key to which the program to be written is to be attached; then type in the overlay number on which that key is to be located; then press the keys which will make up the desired program; at the end press PROGRAM again.

REPEAT Press REPEAT; then press any repeatable key (i.e., either a hand programmed key, or a console programmed key whose program ends on the same overlay on which the key itself is located); then type in on the numerical keys the number of times the operation is to be repeated. This repeat operation can, of course, itself be incorporated into a console program.

TALLY This is used only within a console program and is one of two capabilities for program branching. TALLY must be imbedded in some console programmed subroutine; that is to say, it must be one of the series of key pushes which make up some console programmed key. When, in the running of that subroutine,

the computer comes to the point where the TALLY key was pushed, it checks the scale value $s_y$, of the D register. If $s_y$ is positive the computer reduces $s_y$ by 1 and proceeds to the next key in the subroutine; if the scale is 0 or negative, it jumps to the end of this particular subroutine.

COMPARE This operates in the same fashion as TALLY but uses as its criterion the sign of the first y value, $y_1$, of the D register. If this is positive, the computer continues to the next key push; otherwise, it jumps to the end of the subroutine in which COMPARE is imbedded.

(These keys make possible the incorporation of standard programming techniques - loops, tallys, etc. - at the console programming level.)

A3. Display and Output Keys

DISPLAY OVERLAY NUMBER The number of the overlay currently in the computer is displayed on the alphanumeric scope.

ERASE All curves are erased from the CRT.

DISPLAY DISPLAY A causes the function stored in location A to be displayed; pushing A again erases that curve from the scope. Subsequently pushing other keys will cause the curves stored in them to be displayed also, until some other operator key is pressed.

DISPLAY VALUE AND SCALE, BINARY The mantissa of the first y value of the D register and the y scale, $s_y$, of the D register are displayed on the alphanumeric scope.

DISPLAY VALUE, DECIMAL If $y_1$ is the mantissa of the first y value in the D register and $s_y$ the scale of the function, the number $y_1 \cdot 2^{s_y}$ is displayed as a decimal mantissa times a power of 10.

GRAPHICAL INPUT Press POINT-INPUT; then DISPLAY-CROSSHAIR. A crosshair, whose position can be controlled by a lever, is displayed on the screen. After positioning it at any desired point, push TRANSMIT-CROSSHAIR-COORDINATE. The x and y coordinates of the selected point are then transmitted to the computer and a small crosshair symbol is displayed on the scope at that point. The points thus put in are accumulated and can be used in conjunction with the RELATIVE INTERPOLATION key described in Section A1.

PRINT Any curve loaded into the D register will be printed out on the flexwriter in conventional format, i.e., the x and y values will be listed in decimal form.

LABEL After this is pushed, the function keys serve as typewriter keys and can be used to compose any desired alphanumeric message. (Each letter or number is displayed on the alphanumeric scope as it is typed.) This is useful for generating a label to go with a kernel stored on tape, a message which is to be written on tape along with a system dump, or an identifying legend to accompany a hard copy curve when the PRINT key is used.

LEFT SCOPE A word in the display routine is set so that any curve subsequently displayed with the usual DISPLAY key will appear on the lefthand 17 inch CRT.

RIGHT SCOPE A word in the display routine is set so that any curve subsequently displayed with the standard DISPLAY key will appear on the righthand scope.

Alternative Display Formats There are several keys which allow the capability of displaying curves in other than the usual format. Ordinarily 100 straight line segments connecting the 101 points are displayed. However, one can instead display only the 101 dots with no connecting line, or other symbols such as crosses, circles, etc.

A4. System Control Capabilities

The keys in this group allow for convenient management of the entire computer system. Only the first few are needed by the typical user; those with an asterisk are used only by the computer expert and may be disregarded by readers not in that category.

SYSTEM LOAD An entire system - overlays, curves, subroutines, etc. - is loaded from tape into the computer system. Whenever a user starts a period on the machine, he has his tape put on the tape unit and pushes SYSTEM LOAD, thereby putting the entire computer system into the same state it was when he last used it.

SYSTEM DUMP This is the inverse operation to SYSTEM LOAD, and is used at the end of each user's run.

TAPE READ This reada a block of 512 words from magnetic tape into the C and D registers of the computer.

TAPE WRITE This writes contents of the C and D registers as a 512 word block on magnetic tape.

Tape Manipulation There are keys for erasing a block on tape, skipping a block on tape, skipping to an end of file, writing an end of file; rewinding the tape, etc.

DRUM READ* DRUM READ nm reads into the C and D registers, from the drum, the computer program corresponding to Overlay nm. This allows the computer expert to examine or modify the actual machine words comprising the hand programs of this overlay.

DRUM WRITE* This is the inverse of the DRUM READ operation and is used to replace an overlay on the drum after it has been examined or modified.

SUBROUTINE READ* SUBROUTINE READ nml stores the automatic subroutine with identification number nml into the C register where it can be examined or modified by a computer expert.

SUBROUTINE WRITE* This is the inverse of SUBROUTINE READ.

A5. Aids for the Hand Programmer

All of these keys are for the computer expert alone and, like the last items in Section A4, should be ignored by readers who are not in this class. Their descriptions are included here only for completeness.

OVERLAY OUT OVERLAY OUT nm stores the overlay now in the computer onto the drum in the appropriate place. This is necessary after hand program alterations have been made in an overlay.

INSERT This is a convenient method of inserting short hand programs into the system. Press INSERT, then a CM address (4 digits on the numerical keys), then ENTER, then a machine word (10 digits on the numerical keys), then ENTER. Any number of additional machine words can now be typed in (each followed by ENTER); they will be stored in sequence in the locations following the first one. In addition, each word (and the address of the first one) is displayed on the alphanumeric scope.

DO This is simply a convenient means of causing the computer to execute any single instruction on command from the control console. Press DO, then type in on the numerical keys any machine command (again, 10 digits for this particular computer) followed by ENTER.

DISPLAY OF MEMORY CONTENTS This is a convenient means of examining the contents of any portion of the CM memory. Push DISPLAY MEMORY, then type in the four digits specifying an address in the CM. That address and the (10 digit) machine word it contains are then displayed on the alphanumeric scope. If a number n is now entered on the numerical keys, the next n words of the CM memory will be displayed, an operation which can be repeated as often as desired. DISPLAY MEMORY need be pushed again only if one wishes to examine a non-contiguous portion of the memory. The incorporation of this capability into suitable console programs provides the computer expert with a convenient means of dynamically debugging a hand program.

## A6. The SECOND COMPUTER Key

In a class by itself is the SECOND COMPUTER key (although in a logical sense it probably could be included in Section A4). The RW-400 system has two identical computer modules, CM-1 and CM-2. The control console normally communicates directly with CM-1, and CM-2 is not used. However, pressing the second computer key, then any previously programmed key [K], followed by the number of the overlay on which [K] is located, causes the SECOND COMPUTER to carry out whatever program is associated with key [K], taking from the drum the subroutines, curves, and other information needed in doing this. While this is going on, the user at the control console is free to use CM-1 for any of the normal operations, e.g., to examine the results being generated by CM-2, to prepare for the next case to be run, to create new console programs, etc.

## REFERENCES AND NOTES


1. J. C. R. Licklider and W. E. Clark, "On-Line Man-Computer Communication", Proc. of Spring Joint Computer Conference (May 1962). The first two pages of this contain a cogent statement of the motivation for an on-line system and of some general principles to be observed in constructing one.

2. Glen J. Culler and Robert W. Huff, "Solution of Non-Linear Integral Equations Using On-Line Computer Control", Proc. W. J. C. C., May, 1962.

   Glen J. Culler, Burton D. Fried, Robert W. Huff and J. Robert Schrieffer, "Solution of the Gap Equation for a Superconductor", Phys. Rev. Letters 8 399 (1962).

   Glen J. Culler, Burton D. Fried, Robert W. Huff and J. Robert Schrieffer, "Use of On-Line Computing in the Solution of Scientific Problems" (RW Research Laboratory Report, April, 1962, unpublished).


3. We use the term "hand program" to denote a computer program of the classical sort, i.e., a list of machine words, in contrast to a "console program", which, as described below, is essentially a list of key pushes.

4. The term "automatic programming" might be better, but unfortunately it already has a different significance.

5. The numerical keys include also ENTER, which must be pushed at the end of any sequence of numbers. When we give below illustrative lists of key pushes we shall generally omit ENTER, although in actual operation it must always be included.

6. This example is only illustrative, since in an operating system it is more sensible to make SINE a hand programmed key. In the early stages of development of the present system, however, we actually used, for SINE and COSINE, console programs based on 10 terms of the power series for functions with scale $s_y \leq 1$ and repeated use of the double angle formulas when $s_y > 1$.

7. Experience shows that operation by one user for less than one hour or more than two tends to be inefficient.


8. B. D Fried, M. Gell-mann, J. D. Jackson and H. W. Wyld, "Longitudinal Plasma Oscillations in an Electric Field", J. Nuclear Energy; Part C 1 190 (1960).

9. Glen J. Culler and Burton D. Fried, "Plasma Oscillations in an External Electric Field", (to be published).

10. To avoid confusion between operator keys and function keys having the same label, e.g., t, we shall, in writing lists of key pushes like (22), use [ ] for any operator key whose label coincides with that assigned to some function key. Of course, in actually using the console no confusion arises since the operator keys are physically distinct (and separated) from the function keys. Also, since all functions involved in our examples are on the same bank, we omit the bank subscripts, writing simply LOAD and STORE in place of $LOAD_I$ and $STORE_I$.

11. We assume the on-line work to occur during a period of the day when the central computer is being used only for short problems (maximum of a few minutes running time).

12. See, e.g., C. Strachey, "Time Sharing in Large, Fast Computers", Proc. of International Conference on Information Processing, UNESCO, p. 336 (June, 1959), and A. L. Leiner, W. A. Notz, J. L. Smith and R. B. Marimont, "Concurrently Operating Computer Systems", loc. cit., p. 353.

13. Although "complete" in the sense of being very useful for a wide range of problems, the present system is still growing in the sense that this overlay and some of the other extension described in this chapter will be incorporated in the near future.

14. The only complication which can arise concerns operations with functions stored on two different banks. Thus, in place of $Load_I$ A + B which we would use to add two functions stored on I, we use $Load_I$ A $Load_{III}$ + R to add functions on banks I and III; here the $Load_{III}$ key functions only as a bank indicator.

Figure 1. Control console used in the On-Line Computer Center.

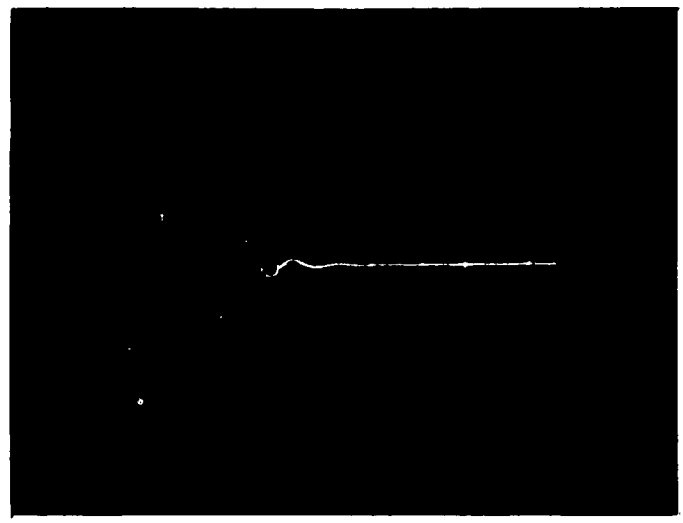


Figure 2. The kernel function $L_e$, defined by (10), as obtained by iterating (18), correcting the result using (21), etc. The slightly damped curve is for k = 0.4; the strongly damped one is for k = 1.0. A dotted curve shows the result for k = 1 obtained by retaining only the two least damped poles in the Laplace transform of $L_e$ when inverting the transform by contour integration. Grid lines: y = 0, $\pm$ 1/2; t = 7.5, 15, 22.5.

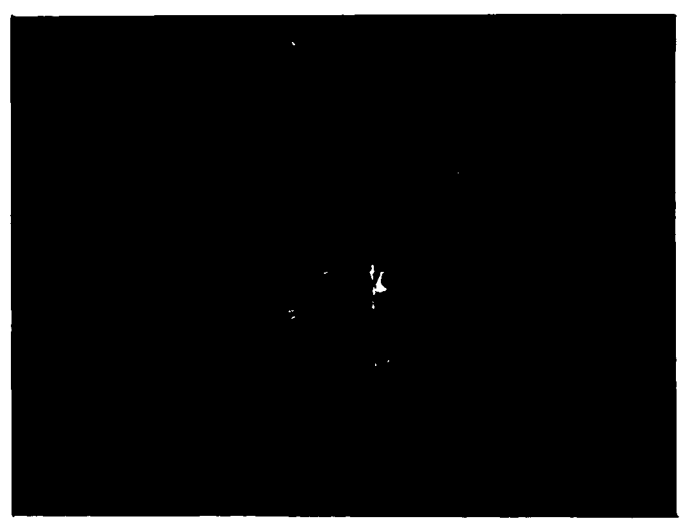


Figure 3. E(t) in the complex plane for $1 \leq t \leq 30$ with k = 0, $\xi$ = 0 and (reading from left to right) u = 0.8, 0.9, 1.0, 1.1, 1.2. These u values bracket the region of resonance, i.e., of growing waves. The curves all start at the point E = 1. Also shown are the real and imaginary E axes and the circles |E| = 8 and |E| = 16.

Figure 4. E(t) for k = 0, $\mathcal{E}$ = 0.1. The range of $d\psi/dt$, $0 \leq \dot{\psi} \leq 3$, includes the values used in Figure 3 (where $\dot{\psi}$ is constant). The approach of E to an approximate limit circle centered at E(t = 0) can be predicted analytically for the single species case ($\delta$ = 0). The circles |E| = 4 and |E| = 8 are shown.

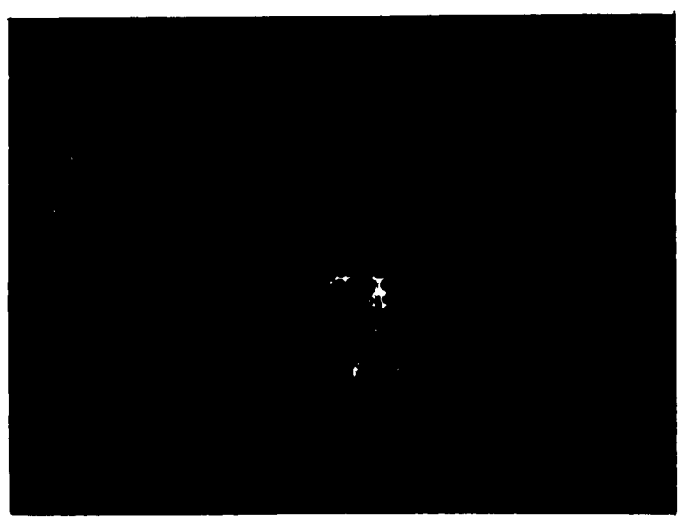


Figure 5. E(t) for k = 0.4, $\mathcal{E}$ = 0 and (from left to right) u = 0.9, 1.0, 1.1, 1.14, 1.2. Note the increased damping as compared with the k = 0 case. The circle |E| = 8 is shown.

Figure 6. E(t) for k = 0.4, $\varepsilon$ = 0.1. The analytic solution for the single species case ($\delta$ = 0) shows that the radius of the limit "circle" approached by E should be a slowly decreasing function of t. The circles |E| = 4 and |E| = 8 are shown.

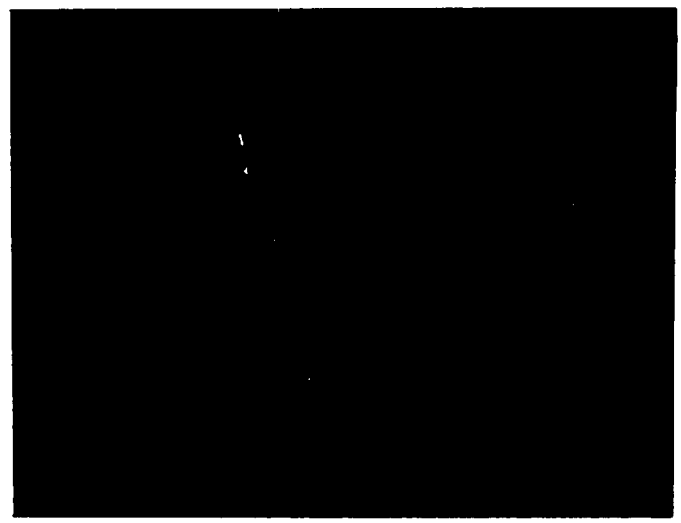


Figure 7. E(t) for k = 1.0, $\varepsilon$ = 0 and (left to right) u = 0.8, 1.0, 1.2, 1.3, 1.4, 1.5, 1.7, 1.8. The high frequency (electron plasma) oscillations, $\omega \approx 1$, damp out completely during the time interval depicted, leaving only low frequency waves (associated with ion motion) which appear as bright "tails" on the curves. Arcs of the circles |E| = 1 and |E| = 2 are shown.

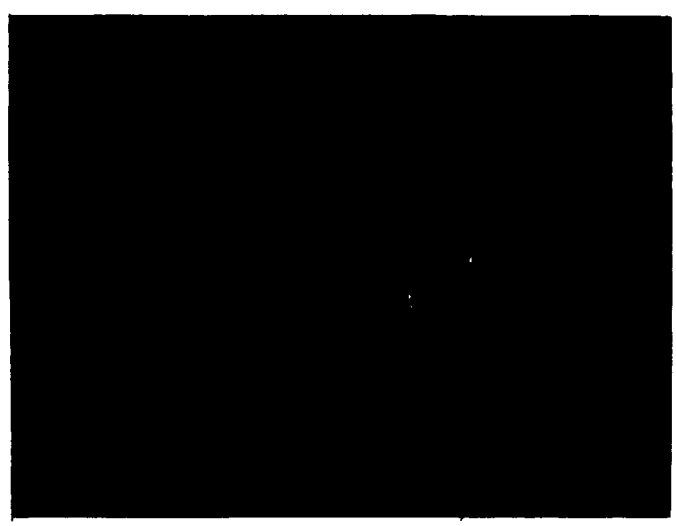


Figure 8. E(t) for k = 1, $\varepsilon$ = 0.1. The limit circle for $\delta$ = 0 in this case should damp as $e^{-0.4t}$. The circles |E| = 1 and |E| = 2 are shown.

## B. ON LINE SYSTEM PROGRAMMING

This section provides a record of most of the hand programming done during the contract. In certain cases patches exist that normally would have been corrected prior to publication but the programs do work and problem solving takes priority over vanity.

Table A shows the DAC keys designated by the CM address to which the programs jump to when that button is pressed. The six programs that are common on all overlays are also shown.

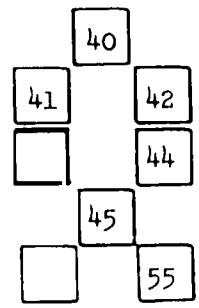
Table B lists the hand programmed buttons on the system overlays.

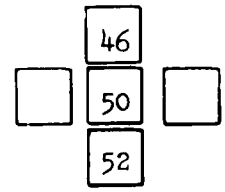
Table C lists the computer memory assignment for the on-line system.

Table D lists the storage assignment for the DMB and DM.

Following this material is a complete listing of programs as shown in the index on Page 69.

| | | | | |
|---|---|---|---|---|
| 1 | 7 | 15 | 24 | 32 |
| 2 | 10 | 16 | 25 | 33 |
| 3 | 11 | 20 | 26 | 34 |
| 4 | 12 | 21 | 27 | 35 |
| 5 | 13 | 22 | 30 | 36 |
| 6 | 14 | 23 | 31 | 37 |




Programs Common on All Overlays

| DAC Key | Program |
|---|---|
| 1 | BEGIN |
| 2 | PROGRAM |
| 3 | REPEAT |
| 4 | OVERLAY IN |
| 5 | OVERLAY OUT |
| 6 | INSERT |

Table A

DAC Key Designation by CM Address Jumped To and Programs Common on All Overlays

| DAC Key | OV No. | 01 | 02 | 4 | 5 | 6 | 7 | 10 | 17 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-6 | | Common on all overlay. | | See Table A. | | | | | | |
| 7 | | OV 20 | OV 20 | Do | Do | Do | Do | OV 20 | Do | Do |
| 10 | | + | + | Kill L | Erase | | | | | |
| 11 | | - | - | ← D | D + | | | | | |
| 12 | | X | X | \|Dy\| | D- | | | | | |
| 13 | | ·/· | ·/· | \|Dx&y\| | OV | | | | | |
| 14 | | √‾‾ | | | PE | | | | | |
| 15 | | △ | Float | D Cont | | | Nxt line | OV 01 | | Reflect |
| 16 | | Σ | Extract | Kill R | | | $CBS_{10}$ | OV 02 | | Substitute |
| 20 | | OV 10 | OV 10 | D → | | | $CBS_{8}$ | | | OV 10 |
| 21 | | | | \|Dx\| | | | | | | |
| 22 | | | | Auto-Ev | | | | | | |
| 23 | | X Gen | X Gen | Evaluate | | | | | | |
| 24 | | $=_1$ | $=_1$ | $=_1$ | | | | $=_1$ | | Tally |
| 25 | | $=_2$ | $=_2$ | $=_2$ | | | | $=_2$ | | Compare |
| 26 | | $=_3$ | $=_3$ | $=_3$ | | | | $=_3$ | | |
| 27 | | $=_4$ | $=_4$ | $=_4$ | | | | $=_4$ | | |
| 30 | | $=_5$ | $=_5$ | $=_5$ | | | | $=_5$ | | |
| 31 | | $=_6$ | $=_6$ | $=_6$ | | | | $=_6$ | | |
| 32 | | $L_1$ | $L_1$ | $L_1$ | | | | $L_1$ | | |
| 33 | | $L_2$ | $L_2$ | $L_2$ | | | | $L_2$ | | |
| 34 | | $L_3$ | $L_3$ | $L_3$ | | | | $L_3$ | | |
| 35 | | $L_4$ | $L_4$ | $L_4$ | | | | $L_4$ | | |
| 36 | | $L_5$ | $L_5$ | $L_5$ | | δ | | $L_5$ | | |
| 37 | | $L_6$ | $L_6$ | $L_6$ | | | | $L_6$ | Repack | |
| 40 | | Suppress | | | | | | | | |
| 41 | | | | | | | | | | |
| 42 | | Expand X | | | | | | | | |
| 44 | | Contract X | | | | | | | | |
| 45 | | Display | Display | | | | | Display | | |
| 46 | | Continue | Continue | Continue | Continue | | | Continue | Continue | |
| 50 | | Interrupt | Interrupt | Interrupt | Interrupt | | | Interrupt | Interrupt | |
| 52 | | Seal | Seal | Seal | Seal | | | Seal | Seal | |
| 55 | | | | | | | | | | |
| | | Load K | Load K | | | | | Load K | | |

Table B

Hand Program Buttons on System Overlays

| DAC Key | 21 | 22 | 23 | 24 | 25 | 30 | 34 | 35 | 36 | 37 | Blank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-6 | | Common on All Overlays. | | See Table A. | | | | | | | |
| 7 | Do | Do | Do | Do | Do | Do | Do | Do | Do | Do | Do |
| 10 | | | | Pt.Input | TM→D | | Memory | | Type | TM R | |
| 11 | | | | Erase | TM→C | | | Cards | | DM R | |
| 12 | | | | Interp. | Skip EOF | | | L Scope | | DMB R | |
| 13 | | | | | | | | | | Clear | |
| 14 | | | | | | | | | D CBS | Initiate | |
| 15 | | | | | D←~TM | | | Line | | Skip EOF | |
| 16 | | | | | C←TM | | | | | TM W | |
| 20 | | | | | Back EOF | | | R Scope | End Type | DM W | |
| 21 | | | | | | | | | | DMB W | |
| 22 | | | | | | | | | | | |
| 23 | | | | | | | | | | BM W | |
| 24 | | | | | | | | Dot | | Tie | |
| 25 | | | | | | | | 0 | | Skip | |
| 26 | | | | | | | | + | | Erase | |
| 27 | | | | | | | | X | | Back | |
| 30 | | | | | | | | 0 | | EOF | |
| 31 | | | | | | | | | | Rewind | |
| 32 | | | | | | | | Dot + line | Erase CBS | Load | |
| 33 | | | | | | | | | Disp-Auto | Dump | |
| 34 | | | Flip D | | | | | | | | |
| 35 | | | Trans T | | | | | | | | |
| 36 | $E^d$ | FW-CBS | $\int T_x$ | | | | | | | | |
| 37 | Sin-cos | FW-curve | $\int$ Trans | | $\int$ Trans | ln D | | Large | Crr. Ret. | | |
| 40 | | | | | | | | | | | |
| 41 | | | | | | | | | | | |
| 42 | | | | | | | | 2nd CM | | | |
| 44 | | | | | | | | | | | |
| 45 | | | | | | | | | | | |
| 46 | Cont. | | Cont. | | Cont. | | Cont. | Cont. | Cont. | | Cont. |
| 50 | Int. | | Int. | | Int. | | Int. | Int. | Int. | | Int. |
| 52 | Seal | | Seal | | Seal | | Seal | Seal | Seal | | Seal |
| 55 | | | | Cross hair | | | | | | | |



Table B (Continued)

Hand Program Buttons on System Overlays

| Computer Address | Use |
|---|---|
| 1 | Search word for overlay in and out |
| 2-16 | Jump to these addresses when DAC P 1-16 key pushed |
| 17 | Jump to 400 |
| 20-37 | DAC F Key 20-37 |
| 40-51 | DAC D Key 1-10 |
| 53 | Link 72 53 400 to get number |
| 54 | D keys |
| 55 | Cross haris |
| 56 | Light Gun Left |
| 57 | Light Gun Right |
| 60-77 | Constant |
| 101-377 | Overlays |
| 376 | Overlay number for CBS display |
| 377 | Overlay number |
| 400-700 | DAC Reader |
| 700-777 | Automatic Subroutine |
| 777 | Subroutine number |
| 1000 | Search Word for C register |
| 1000-1377 | C register, 1000 = X, 1001 = y. |
| 1375 | C register scale |
| 1400 | Search word for D register |
| 1400-1776 | D register |
| 1775 | D register scale |

Table C

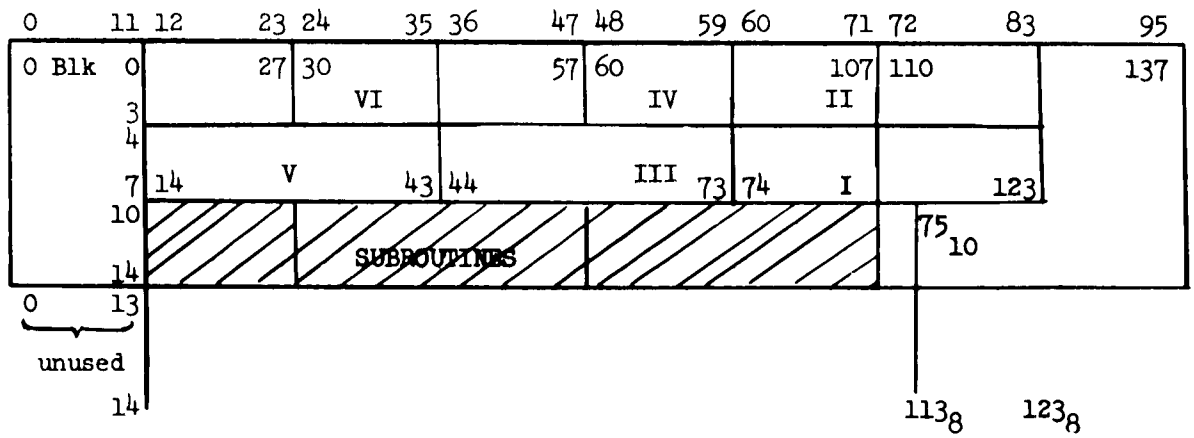
Computer Memory Assignment for the On-Line System

STORAGE

4 drums X 24 bands/drum = 96 bands

13 blocks X 64 words/block = 832 words = $1500_8$ words/band

Blocks (0-14)




| SUBROUTINE | 0 | 1 | 11 | | |
|---|---|---|---|---|---|
| | 100 | 101 | 111 | | |
| | 200 | 201 | 211 | | |
| | 300 | 301 | 311 | | |
| | 400 | 401 | 411 | | 500 |

SUBROUTINES

Bands 14-113, $320_{10}$, or $500_8$ total subroutines

Blocks 10-14 = 5 x 100 = 500

Table D

Storage Assignment for the DMB and DM

| Curves | Bands | Blocks | Top Left D Key | | Next D Key | |
|---|---|---|---|---|---|---|
| | | | $Band_8$ | $Block_8$ | $Band_8$ | $Block_8$ |
| L-1 | 74-123 | 4-7 | 74 | 4- | 75 | 4- |
| 2 | 74-123 | 0-3 | 74 | 0 | 75 | 0- |
| 3 | 44-73 | 4-7 | 44 | 4 | 45 | 4 |
| 4 | 44-73 | 0-3 | 44 | 0- | 45 | 0- |
| 5 | 14-43 | 4-7 | 14 | 4- | 15 | 4- |
| 6 | 14-43 | 0-3 | 14 | 0- | 15 | 0- |

ID WORDS

Subroutines

Word 777 in op.

| Block No - 10 | Band No -14 |
|---|---|
| 3 bits | 6 bits |

Add $10_8$ to block

Add $14_8$ to band

Words 1177, 1277, 1377, 1477, 1577 during dump or load

CURVE

1776

| Band No. 7 bits | Block No. 4 bits. |
|---|---|

DM STORAGE

Overlay AB, B is band number, A is search word.

| | SW |
|---|---|
| A = 0 | 0000 |
| 1 | 0400 |
| 2 | 1000 |
| 3 | 1400 |

Table D (Continued)

Storage Assignment for the DMB and DM

## Index for Program Listings

DAC READER

```
31 0076 0403  0400
33 0000 0000
75 1000 0402
70 0000 0426
70 0000 0405
30 0043 0001
36 0077 0407
70 0000 0430
31 0376 0074  0410
42 1434 0011
42 1002 0223
40 0073 0001
70 0000 0400
00 1777 0000
75 1000 0402
00 0000 1777
72 0403 0401  0420
36 0072 0422
70 0000 0007
72 0053 0400
30 0443 0000
72 0403 0402
71 0466 0424
70 0000 0516
72 0403 0401  0430
70 0000 0053
00 0001 0001
00 0000 0144
00 0002 0002
00 0000 0020
00 0000 0002
77 1770 0000
72 0403 0401  0440
05 0071 0000
73 0070 0421
70 0000 0054
31 0062 0466
33 0000 0000
72 0457 0451
70 0000 0055
70 0000 0444  0450
75 1000 0451
01 0467 0000
30 0045 0000
71 0466 0451
72 0403 0402
01 0467 0000
70 0000 0464
31 0060 0466  0460
33 0000 0000
72 0457 0451
70 0000 0056
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0040

70 0000 0400  0470
00 0001 0000
72 0420 0400
31 0474 0420
72 0403 0401
36 0072 0643
72 0427 0423
01 0060 0630
70 0000 0641  0500
71 0504 0505
31 0061 0504
70 0000 0400
00 0000 0001
31 0062 0466
72 0427 0423
36 0417 0517
31 0522 0521  0510
72 0427 0423
31 0061 0465
30 0441 0000
31 0063 0466
72 0427 0425
71 0465 0513
34 0000 0530
06 0061 0517  0520
70 0000 0526
70 0000 0510
34 0000 0527
31 0523 0517
72 0521 0511
37 0000 0000
70 0000 1760
70 0000 0400  0530
20 1762 0176
75 1000 0532
70 0000 0400
71 0164 0527
00 0001 1777
00 0000 0310
00 0000 0000
42 1400 0001  0540
70 0217 0541
42 1603 0000
42 1604 0001
41 0700 0070
70 0000 0551
72 0545 0540
70 0000 0711
72 0545 0540  0550
70 0000 0722
00 0000 0002
00 0000 0000
00 1777 1777
00 0001 1777
00 0000 0310
00 0077 0017

34 0000 0552  0560
70 0000 0600
31 0564 0530
70 0000 0600
70 0000 0624
00 0000 0017
70 0000 0501
70 0000 0405
00 0000 1400  0570
00 0007 0000
34 0000 0436
70 0000 0624
31 0414 0402
72 0402 0400
07 0000 0436
70 0000 0701
31 0060 0436  0600
72 0721 0546
31 0552 0777
72 0623 0614
70 0000 0574
72 0732 0550
72 0623 0614
70 0000 0400
30 0044 0001  0610
30 0012 0000
36 0557 0001
70 0000 0616
07 0000 0777
72 0613 0610
05 0556 0000
36 0555 0621
42 1420 0010  0620
42 1002 0350
41 0700 0100
70 0000 0607
06 0061 0777
72 0623 0614
70 0000 0576
75 1000 0402
00 0000 0000  0630
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000  0640
31 0402 0627
72 0402 0643
71 0630 0026
31 0627 0402
70 0000 0400
31 0676 0001
70 0000 0661
```

DAC READER

```
31 0060 0466  0650
72 0427 0423
30 0052 0001
30 0005 0000
36 0570 0001
30 0455 0000
36 0437 0001
70 0000 0661
72 0657 0650  0660
07 0000 0001
36 0571 0664
42 1420 0007
42 1007 0202
41 0001 0376
70 0000 0400
72 0657 0650
07 0000 0001  0670
36 0571 0673
42 1420 0007
42 1007 0222
40 0001 0376
70 0000 0400
00 0010 0001
72 0254 0676
00 0000 0000  0700
72 0402 0403
33 0000 0002
72 0402 0403
33 0000 0012
72 0402 0403
33 0000 0001
70 0000 0605
33 0000 0000  0710
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000  0720
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000  0730
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
```

```
33 0000 0000  0740
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000  0750
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000  0760
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000  0770
72 0402 0404
33 0000 0000
72 0402 0404
33 0000 0000
70 0000 0572
00 0000 0000
00 0000 0335
```

MODIFIED DAC READER FOR SECOND COMPUTER

```
70 0000 0641  0500
71 0504 0505
00 0000 0000
27 1212 1721
00 0200 0000
31 0001 0001
42 1430 0011
42 1002 0223
40 0503 0001  0510
42 1404 1001
70 1001 0512
42 1400 0002
70 0217 0514
42 1604 1274
31 1777 0501
31 1777 0502
07 0000 0501  0520
72 0657 0652
72 0666 0661
31 0470 0666
42 1404 0000
72 0402 0502
70 0000 0505
70 0000 1760
34 0000 0000  0530
```

BUFFER BLOCK ONE

```
42 0207 0000  0000
70 0217 0701
42 1603 0000
42 1604 0100
70 0000 0000
70 0217 0705
42 1604 0000
42 1603 0100
70 0000 0000  0010
31 0060 1005
72 0704 0701
41 1005 0300
31 0777 1001
31 0402 1002
72 0710 0745
31 0060 1000
40 1000 0300  0020
70 0000 0602
31 0060 1000
72 0704 0701
41 1000 0300
31 1001 0777
31 1002 0402
72 0710 0751
31 0060 1005  0030
40 1005 0300
70 0000 0606
00 0000 0000
42 1400 0001
70 0217 1036
42 1603 0000
42 1604 0000
40 1000 0707  0040
70 0000 0000
00 0000 0000
70 0000 0000
70 0000 0000
31 0630 1003
31 0643 1004
31 0627 1005
70 0000 0705  0050
31 1003 0630
31 1004 0643
31 1005 0627
70 0000 0705
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
42 1410 0015
31 0060 1000
42 1000 1211
41 1000 0777
70 0000 0400
42 1410 0017
42 1000 1271
31 0060 1000  0110
40 1000 0777
70 0000 0400
72 0657 0650
73 0000 0123
34 0000 1000
36 0571 0120
42 1420 0007
42 1000 0202  0120
41 1000 0376
70 0000 0400
07 0000 0676
70 0000 0115
07 0000 1376
72 0657 0652
73 0000 0136
34 0000 1000  0130
36 0571 0133
42 1420 0007
42 1000 0222
40 1000 0376
70 0000 0400
07 0000 0676
70 0000 0130
31 0061 0466  0140
72 0427 0423
72 0613 0610
05 0536 0000
36 0535 0147
31 0060 1000
42 1420 0010
42 1002 0000
41 1000 0100  0150
70 0000 0400
07 0000 1077
72 0613 0610
05 0536 0000
36 0535 0157
42 1420 0010
42 1006 0000
40 1000 0100  0160
70 0000 0400
00 0000 0000
00 0000 0000
00 0000 0477
00 0000 0035
00 0000 0000
77 1777 1777
72 0105 0101  0170
31 0414 0105
02 0167 1376
71 1376 0400
72 0105 0101
72 0135 0125
72 0105 0101
06 0061 1376
36 0067 0166  0200
30 0046 1375
03 0166 1376
30 0052 0000
04 0473 1375
34 0000 1375
72 0135 0125
71 0165 0177
72 0105 0101  0210
72 0161 0152
06 0061 1077
71 0164 0211
72 0105 0101
72 1042 1035
72 0105 0101
72 0135 0125
33 0000 0037  0220
72 0657 0652
70 0000 0661
72 0505 0222
72 0505 0223
72 0505 0224
72 0505 0225
72 0505 0226
72 0505 0227  0230
72 0505 0230
72 0505 0231
72 0505 0232
72 0505 0233
72 0505 0234
72 0505 0235
72 0505 0236
72 0505 0237  0240
72 0505 0240
72 0505 0241
72 0505 0242
72 0505 0243
72 0505 0244
72 0505 0245
72 0505 0246
```

BUFFER BLOCK ONE

```
72 0505 0247  0250
72 0505 0250
72 0505 0251
72 0505 0252
72 0505 0253
72 0505 0254
72 0505 0255
72 0505 0256
72 0505 0257  0260
72 0505 0260
72 0505 0261
72 0505 0262
72 0505 0263
72 0505 0264
72 0505 0265
72 0505 0266
72 0505 0267  0270
72 0505 0270
72 0505 0271
72 0505 0272
72 0505 0273
72 0505 0274
72 0505 0275
72 0505 0276
72 0505 0277  0300
72 0505 0300
72 0505 0301
72 0505 0302
72 0505 0303
72 0505 0304
72 0505 0305
72 0505 0306
72 0505 0307  0310
72 0505 0310
72 0505 0311
72 0505 0312
72 0505 0313
72 0505 0314
72 0505 0315
72 0505 0316
72 0505 0317  0320
72 0505 0320
72 0505 0321
72 0505 0322
72 0505 0323
72 0505 0324
72 0505 0325
72 0505 0326
72 0505 0327  0330
72 0505 0330
72 0505 0331
72 0505 0332
72 0505 0333
72 0505 0334
72 0505 0335
72 0505 0336
72 0505 0337  0340
72 0505 0340
72 0505 0341
72 0505 0342
72 0505 0343
72 0505 0344
72 0505 0345
72 0505 0346
72 0505 0347  0350
72 0505 0350
72 0505 0351
72 0505 0352
72 0505 0353
72 0505 0354
72 0505 0355
72 0505 0356
72 0505 0357  0360
72 0505 0360
72 0505 0361
72 0505 0362
72 0505 0363
72 0505 0364
72 0505 0365
72 0505 0366
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0000 0000
00 0000 0000
31 0076 0403  0400
33 0000 0000
75 1000 0402
70 0000 0404
70 0000 0405
30 0043 0001
36 0077 0407
70 0000 0470
31 0376 0074  0410
42 1434 0011
42 1002 0223
40 0073 0001
70 0000 0400
00 1777 0000
75 1000 0402
00 0000 1777
72 0403 0401  0420
36 0072 0422
70 0000 0026
72 0053 0400
30 0443 0000
72 0403 0402
71 0466 0424
70 0000 0235
72 0403 0401  0430
70 0000 0053
00 0001 0001
00 0000 0144
00 0002 0002
00 0000 0020
00 0000 0002
77 1770 0000
72 0403 0401  0440
05 0071 0000
73 0070 0421
70 0000 0054
31 0062 0466
33 0000 0000
72 0457 0451
70 0000 0055
70 0000 0444  0450
75 1000 0451
01 0467 0000
30 0045 0000
71 0466 0451
72 0403 0402
01 0467 0000
70 0000 0464
31 0060 0466  0460
33 0000 0000
72 0457 0451
70 0000 0056
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0040
70 0000 0400  0470
00 0001 0000
72 0420 0400
31 0474 0420
72 0403 0401
36 0072 0643
72 0427 0423
01 0060 0630
70 0000 0641  0500
71 0504 0505
31 0061 0504
70 0000 0400
00 0000 0001
31 0062 0466
72 0427 0423
36 0417 0517
31 0522 0521  0510
72 0427 0423
31 0061 0465
30 0441 0000
31 0063 0466
72 0427 0425
71 0465 0513
34 0000 0646
```

BUFFER BLOCK ONE

```
06 0061 0517 0520
70 0000 0510
70 0000 0510
34 0000 0527
31 0523 0517
72 0521 0511
37 0000 0000
07 0000 0416
70 0000 0400 0530
20 1762 0176
75 1000 0532
70 0000 0400
71 0164 0527
00 0001 1777
00 0000 0310
00 0000 0000
42 1400 0001 0540
70 0217 0541
42 1603 0000
42 1604 0001
41 0700 0070
70 0000 0551
72 0545 0540
70 0000 0711
72 0545 0540 0550
70 0000 0722
00 0000 0002
00 0000 0000
00 1777 1777
00 0001 1777
00 0000 0310
00 0077 0017
34 0000 0552 0560
70 0000 0600
31 0564 0530
70 0000 0600
70 0000 0624
00 0000 0017
70 0000 0501
70 0000 0405
00 0000 1400 0570
00 0007 0000
34 0000 0436
70 0000 0624
31 0414 0402
72 0402 0400
07 0000 0436
70 0000 0701
31 0060 0436 0600
72 0721 0546
31 0552 0777
72 0623 0614
70 0000 0574
72 0732 0550
72 0623 0614
70 0000 0400
30 0044 0001 0610
30 0012 0000
36 0557 0001
70 0000 0616
07 0000 0777
72 0613 0610
05 0556 0000
36 0555 0621
42 1420 0010 0620
42 1002 0350
41 0700 0100
70 0000 0607
06 0061 0777
72 0623 0614
70 0000 0576
70 0000 0732
00 0000 0000 0630
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000 0640
31 0402 0627
72 0402 0643
71 0630 0010
31 0627 0402
70 0000 0400
31 0676 0001
70 0000 0661
31 0060 0466 0650
72 0427 0423
30 0052 0001
30 0005 0000
36 0570 0001
30 0455 0000
36 0437 0001
70 0000 0661
72 0657 0650 0660
07 0000 0001
36 0571 0664
42 1420 0007
42 1007 0202
41 0001 0376
70 0000 0400
72 0657 0650
07 0000 0001 0670
36 0571 0673
42 1420 0007
42 1007 0222
40 0001 0376
70 0000 0400
00 0010 0001
72 0254 0676
00 0000 0000 0700
72 0402 0403
33 0000 0002
72 0402 0403
33 0000 0004
72 0402 0403
33 0000 0003
72 0402 0403
33 0000 0000 0710
31 0060 1005
72 0704 0701
41 1005 0300
33 0000 0002
72 0402 0403
72 0710 0745
00 0000 0000
00 0000 0000 0720
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000 0730
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000 0740
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000 0750
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000 0760
00 0000 0000
42 1000 1241
40 1000 0777
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
```

BUFFER BLOCK ONE

```
00 0000 0000  0770
42 1000 1211
41 0001 1777
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
```

BUFFER BLOCK TWO, ADD 1000 TO ADDRESS

```
                                31 1043 1050 0070       31 1157 1140 0160
72 0137 0134                    31 1044 1055            31 0414 1152
31 0067 0464                    31 1045 1060            70 0000 1142
31 1036 1005                    31 1046 1064            31 1157 1401
31 1037 1012                    37 0000 0000            31 0060 1776
03 1776 0640                    34 1375 1376            71 1164 1166
73 0000 1102                    34 1377 1400            71 1401 1164
02 0061 1005                    07 0000 1401            70 0000 1153
71 0464 1005 0010               11 0000 1401 0100       00 0000 0011 0170
31 0067 0464                    70 0000 1117            00 0000 0000
07 0000 0640                    31 1041 1401            00 0000 0031
73 0000 1022                    31 0060 1776            03 0314 1463
02 0061 1012                    71 1103 1105            00 0000 0000
71 0464 1012                    71 1401 1103            00 0000 0000
07 0000 0630                    31 1123 1103            03 0314 1463
37 0067 0060                    07 0000 1005            30 0471 1201
01 1037 1012 0020               36 0417 1111 0110       00 0000 0012 0200
06 0061 0630                    31 0060 0635            73 1170 1206
07 0000 1012                    72 1031 1025            73 1200 1212
36 0417 1024                    31 1115 1031            30 0004 0000
31 1776 0000                    70 0000 1032            30 0471 1175
37 0067 0000                    70 0000 1116            70 0000 1212
30 0047 1374                    72 1101 1047            25 1173 0000
70 0000 1120                    70 0000 1032            34 0000 0000
36 0437 1374 0030               06 0064 1374 0120       05 1174 1174 0210
70 0000 1116                    30 0455 0000            26 1176 1173
42 1430 0011                    70 0000 1030            72 0403 0401
42 1000 0223                    31 0060 1776            31 1177 1204
40 1374 0151                    72 0505 0124            72 1205 1201
70 0000 0400                    72 0505 0125            27 0000 1175
03 1776 0640                    72 0505 0126            36 1175 1174
07 0000 0640                    72 0505 0127            72 0403 0401
20 0000 0000 0040               72 0505 0130 0130       25 1200 0000 0220
00 1777 1777                    72 0505 0131            34 0000 0000
40 0000 0000                    72 0505 0132            72 0403 0402
07 0000 1401                    72 0505 0133            34 0000 1175
34 0000 1401                    40 1374 0151            70 0000 1224
07 0000 1402                    72 0505 0135            27 1200 1174
36 0417 1401                    72 0505 0136            30 1077 1174
31 0433 0464                    40 0000 0144            01 1172 1201
07 0000 1401 0050               77 1777 1777 0140       07 0000 1174 0230
30 0001 0000                    01 0061 0464            30 1277 1174
05 1040 0000                    31 1140 1401            05 1201 1201
30 0005 0000                    31 1140 1402            02 1201 1775
37 1041 1042                    06 0062 1137            71 1175 1225
34 0000 1401                    23 0433 1137            70 0000 1235
06 0062 1050                    34 0000 1140            27 1176 1174
06 0061 1055                    06 0062 1142            30 1277 1174
07 0000 1402 0060               06 0062 1143 0150       05 1775 1775 0240
30 0001 0000                    71 0464 1142            71 1175 1236
05 1040 0000                    70 0000 1160            70 0000 1242
30 0017 0000                    03 0433 0060            31 1776 1171
36 0417 1401                    34 0000 1137            72 1162 1163
06 0062 1060                    07 0000 0433            72 1152 1142
06 0061 1064                    70 0000 1141            70 0000 1246
71 0464 1050                    37 1777 1777            00 0000 0000
```

BUFFER BLOCK TWO, ADD 1000 TO ADDRESS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 72 | 1246 | 1244 | 0250 | 06 | 0061 | 1337 | 0340 | 00 0000 0000 0430 |
| 07 | 0000 | 0367 | | 71 | 1310 | 1337 | | 70 0507 1270 |
| 72 | 1224 | 1201 | | 70 | 0000 | 1360 | | 00 0000 0000 |
| 70 | 0000 | 1266 | | 00 | 0000 | 0000 | | 67 1270 0510 |
| 71 | 1201 | 1263 | | 31 | 1314 | 1316 | | 00 0000 0000 |
| 72 | 1235 | 1225 | | 31 | 1315 | 1317 | | 67 0050 1727 |
| 31 | 0433 | 0464 | | 07 | 0000 | 1313 | | 00 0000 0000 |
| 31 | 1174 | 1402 | | 30 | 0041 | 0000 | | 66 0631 1146 |
| 06 | 0062 | 1257 | 0260 | 05 | 1313 | 1312 | 0350 | 00 0000 0000 0440 |
| 71 | 0464 | 1257 | | 06 | 0061 | 1323 | | 65 1412 0366 |
| *70 | 0000 | 0400 | | 71 | 1310 | 1323 | | 00 0000 0000 |
| 36 | 1157 | 1201 | | 31 | 0414 | 1032 | | 00 0000 0000 |
| 70 | 0000 | 1270 | | 72 | 1032 | 0400 | | 64 0753 1024 |
| 73 | 0000 | 1256 | | 31 | 0433 | 1310 | | 00 0000 0000 |
| 71 | 1175 | 1254 | | 70 | 0000 | 1320 | | 63 1534 0244 |
| 31 | 1201 | 1775 | 0270 | 07 | 0061 | 1320 | 0360 | 00 0000 0000 0450 |
| 70 | 0000 | 1256 | | 34 | 0000 | 1323 | | 63 0314 1463 |
| 72 | 0505 | 0272 | | 42 | 1430 | 0011 | | 00 0000 0000 |
| 72 | 0505 | 0273 | | 31 | 1361 | 1312 | | 62 1075 0703 |
| 72 | 0505 | 0274 | | 70 | 0000 | 1033 | | 00 0000 0000 |
| 72 | 0505 | 0275 | | 72 | 0505 | 0365 | | 61 1656 0122 |
| 72 | 0505 | 0276 | | 72 | 0505 | 0366 | | 00 0000 0000 |
| 72 | 0505 | 0277 | | 72 | 0505 | 0367 | | 61 0436 1341 |
| 72 | 0505 | 0300 | 0300 | 72 | 0505 | 0370 | 0370 | 00 0000 0000 0460 |
| 72 | 0505 | 0301 | | 72 | 0505 | 0371 | | 60 1217 0561 |
| 72 | 0505 | 0302 | | 72 | 0505 | 0372 | | 00 0000 0000 |
| 72 | 0505 | 0303 | | 72 | 0505 | 0373 | | 60 0000 0000 |
| 72 | 0505 | 0304 | | 72 | 0505 | 0374 | | 00 0000 0000 |
| 72 | 0505 | 0305 | | 00 | 0201 | 0100 | | 57 0560 1217 |
| 72 | 0505 | 0306 | | 00 | 0000 | 0001 | | 00 0000 0000 |
| 72 | 0505 | 0307 | | 00 | 0000 | 0000 | | 56 1341 0437 |
| 72 | 0505 | 0310 | 0310 | 00 | 0000 | 0000 | 0400 | 00 0000 0000 0470 |
| 72 | 0505 | 0311 | | 37 | 1777 | 1565 | | 56 0121 1656 |
| 37 | 1775 | 0070 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 14 | 0177 | 1170 | | 77 | 0560 | 1217 | | 55 0702 1075 |
| 72 | 0505 | 0314 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 72 | 0505 | 0315 | | 76 | 1341 | 0437 | | 54 1463 0315 |
| 72 | 0505 | 0316 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 72 | 0505 | 0317 | | 76 | 0121 | 1656 | | 54 0243 1534 |
| 07 | 0000 | 1401 | 0320 | 00 | 0000 | 0000 | 0410 | 00 0000 0000 0500 |
| 30 | 0045 | 1317 | | 75 | 0702 | 1075 | | 53 1024 0754 |
| 30 | 0052 | 1316 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 07 | 0000 | 1402 | | 74 | 1463 | 0315 | | 52 1605 0173 |
| 30 | 0045 | 1315 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 30 | 0052 | 1314 | | 74 | 0243 | 1534 | | 52 0365 1412 |
| 01 | 1316 | 1313 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 05 | 3131 | 1313 | | 73 | 1024 | 0754 | | 51 1146 0632 |
| 02 | 1315 | 1317 | 0330 | 00 | 0000 | 0000 | 0420 | 00 0000 0000 0510 |
| 25 | 1317 | 0000 | | 72 | 1605 | 0173 | | 50 1727 0051 |
| 15 | 1313 | 1313 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 73 | 1312 | 1344 | | 72 | 0365 | 1412 | | 50 0507 1270 |
| 31 | 1361 | 1312 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 07 | 0000 | 1323 | | 71 | 1146 | 0632 | | 47 1270 0510 |
| 36 | 0417 | 1337 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 31 | 0060 | 0000 | | 70 | 1727 | 0051 | | 47 0050 1727 |
| *72 | 1242 | 1236 | 0263 | 70 | 0000 | 1360 | 0353 | 65 0172 1605 0443 |

BUFFER BLOCK TWO, ADD 1000 TO ADDRESS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 00 | 0000 | 0000 | 0520 | 00 | 0000 | 0000 | 0610 | 00 0000 0000 0700 |
| 46 | 0631 | 1146 | | 13 | 1024 | 0754 | | 35 0702 1075 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 45 | 1410 | 0366 | | 14 | 0243 | 1534 | | 36 0121 1656 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 45 | 0172 | 1605 | | 14 | 1463 | 0315 | | 36 1341 0437 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 44 | 0753 | 1024 | | 15 | 0702 | 1075 | | 37 0560 1217 |
| 00 | 0000 | 0000 | 0530 | 00 | 0000 | 0000 | 0620 | 00 0000 0000 0710 |
| 43 | 1534 | 0244 | | 16 | 0121 | 1656 | | 37 1777 1777 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 43 | 0314 | 1463 | | 16 | 1341 | 0437 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 42 | 1075 | 0703 | | 17 | 0560 | 1217 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 41 | 1656 | 0122 | | 20 | 0000 | 0000 | | 00 0000 0000 |
| 00 | 0000 | 0000 | 0540 | 00 | 0000 | 0000 | 0630 | 00 0000 0000 0720 |
| 41 | 0436 | 1341 | | 20 | 1217 | 0561 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 40 | 1217 | 0561 | | 21 | 0436 | 1341 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 21 | 1656 | 0122 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 00 | 1217 | 0561 | | 22 | 1075 | 0703 | | 00 0000 0000 |
| 00 | 0000 | 0000 | 0550 | 00 | 0000 | 0000 | 0640 | 00 0000 0000 0730 |
| 01 | 0436 | 1341 | | 23 | 0314 | 1463 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 01 | 1656 | 0122 | | 23 | 1534 | 0244 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 02 | 1075 | 0703 | | 24 | 0753 | 1024 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 03 | 0314 | 1463 | | 25 | 0172 | 1605 | | 00 0000 0000 |
| 00 | 0000 | 0000 | 0560 | 00 | 0000 | 0000 | 0650 | 00 0000 0000 0740 |
| 03 | 1534 | 0244 | | 25 | 1412 | 0366 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 04 | 0753 | 1024 | | 26 | 0631 | 1146 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 05 | 0172 | 1605 | | 27 | 0050 | 1727 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 05 | 1412 | 0366 | | 27 | 1270 | 0510 | | 00 0000 0000 |
| 00 | 0000 | 0000 | 0570 | 00 | 0000 | 0000 | 0660 | 00 0000 0000 0750 |
| 06 | 0631 | 1146 | | 30 | 0507 | 1270 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 07 | 0050 | 1727 | | 30 | 1727 | 0051 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 07 | 1270 | 0510 | | 31 | 1146 | 0632 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 10 | 0507 | 1270 | | 32 | 0365 | 1412 | | 00 0000 0000 |
| 00 | 0000 | 0000 | 0600 | 00 | 0000 | 0000 | 0670 | 00 0000 0000 0760 |
| 10 | 1727 | 0051 | | 32 | 1605 | 0173 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 11 | 1146 | 0632 | | 33 | 1024 | 0754 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 12 | 0365 | 1412 | | 34 | 0243 | 1534 | | 00 0000 0000 |
| 00 | 0000 | 0000 | | 00 | 0000 | 0000 | | 00 0000 0000 |
| 12 | 1605 | 0173 | | 34 | 1463 | 0315 | | 00 0000 0000 |

```
BUFFER BLOCK TWO,  ADD 1000 TO ADDRESS

00 0000 0000    0770
40 0001 0777
00 0000 0000
00 0000 0000
00 0000 0000
40 0001 0310
00 0000 0000
72 0254 0775
```

BLANK SUBROUTINE

```
                                                72 0402 0404  0070
                                                33 0000 0000
    72 0402 0404                                72 0402 0404
    33 0000 0000                                33 0000 0000
    72 0402 0404                                72 0402 0404
    33 0000 0000                                33 0000 0000
    72 0402 0404                                70 0000 0572
    33 0000 0000                                00 0000 0000
    72 0402 0404  0010
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404  0020
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404  0030
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404  0040
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404  0050
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404  0060
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
    72 0402 0404
    33 0000 0000
```

BLANK OVERLAY

```
                                        00 0000 0053  0070
                                        00 0000 0037
70 0000 0646                            00 0000 0077
70 0000 0472                            20 0012 0001
70 0000 0660                            00 0231 0700
70 0000 0667                            00 0001 0400
70 0000 0501                            70 0000 0404
70 0000 0523                            00 0000 0070
70 0000 0000  0010                      00 0000 0000  0100
70 0000 0000                            70 0000 0560
70 0000 0000                            72 0505 0101
70 0000 0000                            72 0505 0102
70 0000 0000                            72 0505 0103
70 0000 0000                            72 0505 0104
70 0000 0000                            72 0505 0105
70 0000 0400                            72 0505 0106
70 0000 0000  0020                      72 0505 0107  0110
70 0000 0000                            72 0505 0110
70 0000 0000                            72 0505 0111
70 0000 0000                            72 0505 0112
70 0000 0000                            72 0505 0113
70 0000 0000                            72 0505 0114
70 0000 0000                            72 0505 0115
70 0000 0000                            72 0505 0116
70 0000 0000  0030                      72 0505 0117  0120
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000  0040                      72 0505 0347  0350
70 0000 0000                            72 0505 0350
70 0000 0000                            72 0505 0351
70 0000 0000                            72 0505 0352
70 0000 0000                            72 0505 0353
70 0000 0000                            72 0505 0354
70 0000 0605                            72 0505 0355
70 0000 0000                            72 0505 0356
33 0000 0000  0050                      72 0505 0357  0360
70 0000 0560                            72 0505 0360
70 0000 0372                            72 0505 0361
70 0000 0424                            72 0505 0362
70 0000 0000                            72 0505 0363
70 0000 0000                            72 0505 0364
70 0000 0000                            72 0505 0365
70 0000 0000                            72 0505 0366
00 0000 0000  0060                      72 0505 0367  0370
00 0000 0001                            72 0505 0370
00 0000 0002                            72 0607 0605
00 0000 0003                            31 0414 0607
00 0000 0004                            06 0062 0520
00 0000 0005                            70 0000 0400
00 0000 0006                            00 0201 0100
00 0000 0007                            00 0000 0000
```

```
                                    00 0000 0052 0070       07 0061 0520 0160
                                    00 0000 0037            36 0417 0162
70 0000 0646                        00 0000 0077            31 0157 0721
70 0000 0400                        20 0012 0001            72 0530 0521
70 0000 0660                        00 0000 0000            31 0777 0200
70 0000 0666                        00 0000 0000            31 0676 0001
70 0000 0501                        70 0000 0404            72 0675 0670
70 0000 0524                        00 0000 0070            31 0553 0156
72 0001 0100 0010                   31 0120 0501 0100       42 1400 0001 0170
72 0001 0100                        06 0432 0100            70 0217 0171
72 0001 0100                        71 0104 0100            42 1603 0000
72 0001 0100                        70 0000 0105            42 1604 0400
72 0001 0100                        00 0000 0036            41 0377 0300
72 0001 0100                        02 0061 0001            07 0000 0156
72 0001 0100                        36 0417 0513            72 0657 0652
72 0001 0100                        31 0200 0777            70 0000 0661
72 0001 0100 0020                   06 0061 0777 0110       00 0000 0003 0200
72 0001 0100                        72 0623 0614            31 0567 0404
72 0001 0100                        31 0414 0600            31 0402 0520
72 0001 0100                        70 0000 0501            72 0402 0403
72 0001 0100                        00 0000 0000            75 1000 0504
72 0001 0100                        00 0000 0000            34 0000 0436
72 0001 0100                        00 0000 0000            11 0565 0000
72 0001 0100                        72 0402 0400            73 0000 0504
72 0001 0100 0030                   72 0666 0660 0120       07 0000 0520 0210
72 0001 0100                        31 0414 0666            36 0417 0514
72 0001 0100                        72 0600 0371            36 0417 0516
72 0001 0100                        31 0530 0600            07 0000 0436
72 0001 0100                        31 0101 0000            36 0554 0000
72 0001 0100                        03 0061 0505            02 0061 0516
72 0001 0100                        36 0417 0512            06 0061 0000
72 0001 0100                        36 0417 0403            31 0566 0404
70 0000 0400 0040                   07 0401 0777 0130       70 0000 0701 0220
70 0000 0400                        34 0000 0000            07 0000 0777
70 0000 0400                        31 0403 0000            72 0613 0610
70 0000 0400                        07 0000 0377            05 0556 0000
70 0000 0400                        72 0657 0652            36 0555 0526
70 0000 0400                        72 0675 0670            42 1420 0010
70 0000 0400                        31 0377 0553            42 1006 0000
70 0000 0400                        31 0536 0561            40 0700 0100
70 0000 0400 0050                   33 0000 0521 0140       70 0000 0624 0230
70 0000 0400                        36 0417 0573            00 0000 0000
70 0000 0400                        31 0676 0001            31 0414 0402
70 0000 0400                        72 0666 0661            72 0402 0400
70 0000 0400                        31 0414 0666            72 0647 0517
70 0000 0400                        31 0414 0675            72 0666 0661
70 0000 0400                        70 0000 0150            70 0000 0160
00 0000 0000                        31 0060 0436            00 0000 0000
00 0000 0000 0060                   31 0201 0501 0150        02 0061 0070 0240
00 0000 0001                        06 0432 0150            31 0010 0003
00 0000 0002                        71 0154 0150            31 0010 0005
00 0000 0003                        70 0000 0240            06 0061 0242
00 0000 0004                        00 0000 0036            71 0070 0242
00 0000 0005                        72 0530 0521            31 0414 0100
00 0000 0006                        00 0000 0000            72 0100 0532
00 0000 0007                        70 0000 0605            31 0260 0073
```

OVERLAY 00

```
31 0261 0376    0250
72 0414 0410
31 0060 0376
31 0470 0414
31 0010 0004
31 0010 0002
72 0414 0400
70 0000 0646
27 1172 1717    0260
00 0000 0400
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000    0270
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000    0300
42 1000 0222
41 0500 0033
70 0000 0400
03 0001 0001
72 0667 0663
31 0414 0667
31 0525 0500
70 0000 0501    0310
31 0416 0402
31 0645 0404
31 0530 0573
07 0000 0377
72 0657 0652
72 0667 0663
31 0414 0673
03 0001 0001    0320
72 0665 0661
31 0777 0200
31 0414 0665
70 0000 0504
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000    0330
71 0504 0505
31 0061 0504
70 0000 0400
00 0000 0001
31 0062 0466
72 0427 0423
36 0417 0517
31 0522 0521    0340
72 0427 0423
31 0061 0465
30 0441 0000
31 0063 0466
72 0427 0425
71 0465 0513
34 0000 0530
06 0061 0517    0350
70 0000 0526
70 0000 0510
34 0000 0527
31 0523 0517
72 0521 0511
37 0000 0000
70 0000 0700
34 0000 0000    0360
31 0001 0001
75 1000 0532
70 0000 0400
71 0164 0527
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000    0370
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0201 0000
00 0000 0000
```

OVERLAY 01

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0055
70 0000 0216   0010
70 0000 0222
70 0000 0233
70 0000 0240
70 0000 0301
70 0000 0350
70 0000 0340
70 0000 0400
33 0000 0010   0020
72 0657 0652
70 0000 0661
70 0000 0332
06 0064 0140
06 0130 0140
06 0064 0140
06 0130 0140
06 0064 0140   0030
70 0000 0141
06 0064 0140
06 0130 0140
06 0064 0140
06 0130 0140
06 0064 0140
70 0000 0334
70 0000 1354   0040
70 0000 0000
70 0000 0266
70 0000 0000
70 0000 0273
70 0000 0330
70 0000 0605
70 0000 0000
33 0000 0000   0050
70 0000 0560
70 0000 0370
70 0000 0424
70 0000 0116
33 0000 0020
70 0000 0021
70 0000 0000
00 0000 0000   0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053   0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0301 0100
00 0001 0400
70 0000 0404
00 0000 0070
70 0000 0560   0100
42 1420 0010
42 1003 0044
41 1000 0376
70 0000 0174
42 1420 0010
42 1002 1704
41 1400 0376
70 0000 0137   0110
42 1420 0010
42 1007 0164
40 1400 0376
70 0000 0150
72 0054 0400
01 0125 0124
71 0124 0120
07 0000 0124   0120
30 0044 0000
05 0136 0124
70 0000 0135
00 0000 1704
00 0000 0055
00 0000 1704
00 0000 0300
00 0000 0574   0130
06 0127 0140
31 0140 0126
02 0140 0140
72 0123 0363
36 0555 0106
72 0110 0105
70 0000 0400
00 0000 0000   0140
06 0127 0140
31 0140 0126
02 0140 0140
72 0123 0115
34 0000 1776
36 0555 0112
72 0114 0111
70 0000 0400   0150
72 1023 0115
36 0555 0102
72 0104 0101
70 0000 0154
07 0000 1314
30 0000 1314
26 1314 1714
06 0434 0157   0160
06 0062 0155
06 0062 0156
71 0464 0155
70 0000 0336
07 0000 1002
07 0000 1402
30 0000 1002
30 0000 1402   0170
72 0123 0115
36 0555 0102
72 0104 0101
70 0000 0227
30 0041 1402
30 0001 1402
70 0000 0336
72 0174 0171   0200
03 1375 1775
73 0060 0210
31 0165 0155
30 0052 0156
06 0167 0156
02 0157 0157
70 0000 0231
03 1775 1375   0210
31 1375 1775
31 0166 0155
30 0052 0156
06 0170 0156
70 0000 0206
72 0207 0200
02 0157 0157
70 0000 0252   0220
01 1000 1000
72 0307 0200
70 0000 0253
34 0000 1002
31 1000 1402
72 0174 0171
33 0000 0000
72 0207 0203   0230
70 0000 0234
00 0000 0000
72 0231 0226
06 1375 1775
70 0000 0246
30 0041 0000
06 1000 1002
72 0231 0226   0240
02 1375 1775
70 0000 0247
00 0000 0000
02 1002 1402
04 0000 0000
06 0245 0157
06 0245 0157
```

OVERLAY 01

```
06 0245 0157    0250
06 0245 0157
06 0245 0157
06 0244 0157
31 0433 0464
70 0000 0155
00 0000 0000
31 0433 0464
34 0000 0262    0260
36 0417 0263
06 0062 0260
06 0062 0261
71 0464 0260
70 0000 0265
31 0175 0261
31 0166 0260
72 0265 0257    0270
02 0061 1775
70 0000 0400
31 0176 0261
31 0166 0260
72 0265 0257
06 0061 1775
70 0000 0400
00 0000 0000    0300
02 0300 0300
72 0207 0200
07 0000 1775
36 0061 0300
31 0300 0312
07 0000 1775
30 0001 1775
70 0000 0250    0310
30 0001 1002
72 0277 0273
31 0414 0277
31 0311 0261
31 0165 0260
72 0265 0257
70 0000 0306
31 0414 0137    0320
70 0000 0131
42 1400 0001
70 0217 0323
42 1603 0000
42 1604 1001
41 1000 0376
70 0000 0331
72 0327 0322    0330
70 0000 1001
72 0327 0322
70 0000 1163
31 0414 0137
70 0000 0131
02 0157 0157
70 0000 0400
31 0237 0157    0340
31 0224 0156
31 0166 0155
72 0164 0354
31 0225 0157
31 0166 0156
31 0177 0164
70 0000 0254
31 0221 0157    0350
72 0347 0341
07 1002 1002
01 1004 1000
06 0062 0225
72 0164 0254
02 0062 0225
31 0370 0347
31 0177 0164    0360
31 0060 1000
70 0000 0400
72 0053 0115
34 0000 0367
72 0327 0322
70 0000 1250
00 0000 0000
72 0607 0605    0370
31 0414 0607
06 0062 0520
70 0000 0400
70 0000 0560
70 0505 0374
00 0201 0100
00 0000 0001
```

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0055
70 0000 0275
70 0000 0277
70 0000 0307
70 0000 0313
70 0000 0333
70 0000 0345
31 0060 1775
70 0000 0400
33 0000 0010    0020
72 0657 0652
70 0000 0661
70 0000 0374
06 0064 0140
06 0130 0140
06 0064 0140
06 0130 0140
06 0064 0140    0030
70 0000 0141
06 0064 0140
06 0130 0140
06 0064 0140
06 0130 0140
06 0064 0140
70 0000 0213
72 0607 0605    0040
31 0414 0607
06 0062 0520
70 0000 0400
70 0000 0560
70 0000 0155
70 0000 0605
00 0000 0000
33 0000 0000    0050
70 0000 0560
70 0000 0040
70 0000 0424
70 0000 0116
33 0000 0020
70 0000 0021
70 0000 0000
00 0000 0000    0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053    0070
00 0000 0037
00 0000 0077
30 0012 0001
00 0201 0200
00 0001 0400
70 0000 0404
00 0000 0070
70 0000 0560    0100
42 1420 0010
42 1003 0204
41 1000 0376
70 0000 0225
42 1420 0010
42 1002 1744
41 1400 0376
70 0000 0137    0110
42 1420 0010
42 1007 0344
40 1400 0376
70 0000 0150
70 0054 0400
01 0125 0124
71 0124 0120
07 0000 0124    0120
30 0044 0000
05 0126 0124
70 0000 0135
00 0000 1744
00 0000 0055
00 0000 1704
00 0000 0300
00 0000 0574    0130
06 0127 0140
31 0140 0126
02 0140 0140
72 0123 0370
36 0555 0106
72 0110 0105
70 0000 1002
00 0000 0000    0140
06 0127 0140
31 0140 0126
02 0140 0140
72 0123 0115
34 0000 1776
36 0555 0112
72 0114 0111
70 0000 0400    0150
04 0000 0000
00 0000 0000
00 0000 0000
00 0000 0030
72 0361 0354
70 0000 1001
31 0417 0153
31 0433 0464    0160
00 0000 0000
30 0077 0000
73 0153 0167
06 0062 0161
71 0464 0161
70 0000 0166
34 0000 0153
70 0000 0164    0170
07 0000 1402
00 0000 0000
13 0000 0153
73 0154 0176
07 0000 0154
30 0052 0000
05 0202 0202
31 0433 0464    0200
00 0000 0000
00 0000 0000
06 0062 0201
06 0062 0202
71 0464 0201
70 0000 0206
30 0040 1402
30 0040 1002    0210
02 0153 1775
02 0153 1375
31 0414 0137
70 0000 0131
31 0433 0464
00 0000 0000
06 0434 0216
71 0464 0216    0220
70 0000 0400
72 0123 0115
36 0555 0102
72 0104 0101
70 0000 0225
31 0171 0161
72 0166 0157
70 0000 0230    0230
31 0252 0161
72 0166 0157
70 0000 0233
31 0171 0201
31 0211 0172
72 0332 0337
70 0000 0243
31 0252 0201    0240
31 0212 0172
72 0332 0326
72 0206 0172
70 0000 0244
06 1002 1402
02 1002 1402
26 1002 1402
```

OVERLAY 02

```
22 1002 1402    0250
40 0000 0001
07 0000 1002
00 0000 0012
72 0225 0222
31 0152 0216
72 0230 0226
02 0061 0153
72 0244 0234    0260
72 0233 0231
02 0061 0153
72 0244 0240
03 1775 1375
70 0072 0271
21 0437 0153
72 0244 0234
70 0000 0015    0270
34 0000 0153
72 0244 0240
70 0000 0215
13 1402 1002
31 0245 0152
70 0000 0254
31 0246 0152
70 0000 0254    0300
72 0225 0222
72 0230 0226
72 0244 0234
72 0233 0231
72 0244 0240
70 0000 0306
72 0306 0301
31 0247 0216    0310
06 1375 1775
70 0000 0215
72 0306 0301
31 0250 0216
31 0253 0152
31 0433 0464
31 0274 0320
13 1402 1002    0320
73 0060 0362
06 0434 0320
71 0464 0320
02 1375 1775
70 0000 0215
31 0210 0202
07 0000 0153
70 0032 0332    0330
02 0336 0202
70 0000 0000
31 0054 0047
33 0000 0000
70 0000 0350
00 0040 0000
31 0207 0202
70 0000 0327    0340
31 0251 0153
72 0244 0234
71 0152 0316
70 0000 0324
72 0230 0226
72 0244 0234
70 0000 0400
72 0054 0560    0350
31 0047 0054
72 0402 0054
70 0000 0605
42 1400 0001
70 0217 0355
42 1603 0000
42 1604 1001
41 1000 0376    0360
70 0000 0156
07 0000 0320
36 0417 0364
13 0000 0000
73 0061 0322
70 0000 0341
00 0000 0000
72 0053 0115    0370
34 0000 0367
72 0361 0354
70 0000 1250
72 0361 0354
70 0000 1163
00 0201 0200
00 0000 0002
```

OVERLAY 04

```
                                                00 0000 0053   0070     70 0000 0251   0160
                                                00 0000 0037            06 0062 0155
    70 0000 0646                                00 0000 0077            06 0062 0156
    70 0000 0472                                20 0012 0001            71 0464 0155
    70 0000 0660                                00 0201 0400            70 0000 0215
    70 0000 0667                                00 0001 0400            07 0000 1002
    70 0000 0501                                70 0000 0404            07 0000 1401
    70 0000 0523                                00 0000 0070            30 0000 1002
    70 0000 0277   0010                         70 0000 0560   0100     30 0000 1401   0170
    70 0000 0324                                70 0000 0560            02 1002 1401
    70 0000 0347                                42 1002 0000            00 0000 0000
    70 0000 0341                                41 1000 0376            42 1420 0010
    70 0000 0267                                70 0000 0104            42 1420 0010
    70 0000 0362                                42 1420 0010            70 0000 0102
    70 0000 0311                                42 1002 0000            31 0433 0464
    70 0000 0400                                41 1400 0376            31 0171 0157
    70 0000 0327   0020                         70 0000 0710   0110     72 0154 0151   0200
    70 0000 0345                                42 1420 0010            03 1375 1774
    72 0134 0373                                42 1006 0000            73 0060 0207
    70 0000 0260                                40 1400 0376            31 0165 0155
    06 0064 0140                                70 0000 0114            30 0052 0156
    06 0130 0140                                72 0054 0400            05 0167 0156
    06 0064 0140                                01 0125 0124            70 0000 0155
    06 0130 0140                                71 0124 0120            03 1774 1375
    06 0064 0140   0030                         07 0000 0124   0120     31 1375 1774   0210
    70 0000 0141                                30 0044 0000            31 0166 0155
    06 0064 0140                                05 0126 0124            30 0052 0156
    06 0130 0140                                70 0000 0152            05 0170 0156
    06 0064 0140                                00 0000 0000            70 0000 0155
    06 0130 0140                                00 0000 0055            31 0200 0222
    06 0064 0140                                00 0000 0000            03 0060 0433
    70 0000 0131                                00 0000 0300            34 0000 0464
    70 0000 0000   0040                         00 0000 0574   0130     13 0000 1401   0220
    70 0000 0000                                06 0127 0140            34 0000 0172
    70 0000 0307                                31 0140 0126            13 0000 1401
    70 0000 0000                                02 0140 0140            73 0172 0235
    70 0000 0305                                72 0123 0115            06 0062 0222
    70 0000 0311                                36 0555 0106            71 0464 0222
    70 0000 0605                                72 0110 0105            31 0433 0464
    70 0000 0000                                70 0000 0400            31 1001 1401
    70 0000 0000   0050                         00 0000 0000   0140     31 1402 1402   0230
    70 0000 0000                                06 0127 0140            06 0062 0230
    70 0000 0000                                31 0140 0126            06 0434 0227
    70 0000 0424                                02 0140 0140            71 0464 0227
    70 0000 0116                                72 0123 0115            70 0000 0246
    70 0000 0000                                34 0000 1776            34 0000 0173
    70 0000 0000                                36 0555 0112            13 0172 0173
    70 0000 0000                                72 0114 0111            73 0000 0224
    00 0000 0000   0060                         72 0000 0400   0150     07 0061 0222   0240
    00 0000 0001                                72 0123 0115            36 0417 0242
    00 0000 0002                                36 0555 0102            07 0000 0000
    00 0000 0003                                72 0104 0174            34 0000 1402
    00 0000 0004                                70 0000 0201            31 0173 0172
    00 0000 0005                                00 0000 0000            70 0000 0224
    00 0000 0006                                00 0000 0000            31 1374 1774
    00 0000 0007                                02 1002 1401            70 0000 0400
```

OVERLAY 04

```
70 0000 0560    0250
70 1073 0254
06 0434 0157
70 0000 0161
07 0000 0157
36 0417 0256
31 0255 1401
70 0000 0252
70 1033 0261    0260
31 0264 0230
31 0265 0227
70 0000 0176
31 1402 1402
31 1001 1401
70 0000 0560
00 0000 0000
00 0000 0143    0270
31 0060 1402
31 0060 1546
00 0000 0061
00 0000 0062
00 0000 0000
31 0001 0001
31 0271 0314
31 0273 0275    0300
70 0000 0310
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
70 0000 0314    0310
31 0001 0001
31 0272 0314
31 0274 0275
00 0000 0000
06 0062 0314
71 0275 0314
70 0000 0400
31 1404 1402    0320
06 0434 0333
31 1710 1712
02 0434 0333
31 0320 0333
31 0321 0334
70 0000 0331
31 0322 0333
31 0323 0334    0330
31 0001 0001
31 0270 0275
31 1714 1712
06 0434 0333
71 0275 0333
70 0000 0400
35 1401 1401
35 1402 1402    0340
72 0355 0345
72 0355 0347
31 0344 0355
70 0000 0400
31 0337 0352
70 0000 0350
31 0340 0352
31 0356 0357    0350
07 0000 0360
00 0000 0000
06 0361 0352
71 0357 0351
70 0000 0400
00 0000 0144
00 0000 0000
37 1777 1777    0360
00 0002 0002
07 0000 0402
70 0065 0400
31 0054 0372
33 0000 0000
72 0054 0560
31 0372 0054
72 0402 0054    0370
70 0000 0605
00 0000 0000
72 0247 0400
70 0000 0605
72 0505 0374
00 0201 0400
00 0000 0004
```

OVERLAY 05

```
                                    00 0000 0053    0070        07 0000 1402    0160
                                    00 0000 0037                00 0000 0143
    70 0000 0646                    00 0000 0077                00 0000 1774
    70 0000 0472                    20 0012 0001                31 0001 0001
    70 0000 0660                    00 0201 0500                31 0155 0175
    70 0000 0667                    00 0001 0400                70 0000 0171
    70 0000 0501                    70 0000 0404                31 0156 0175
    70 0000 0523                    00 0000 0070                70 0000 0171
    70 0000 0110    0010            00 0001 0001    0100        31 0157 0175    0170
    70 0000 0163                    31 0060 1776                31 0001 0001
    70 0000 0166                    31 0060 0640                31 0161 0162
    70 0000 0170                    00 0000 0000                31 0160 0174
    70 0000 0230                    00 0000 0000                07 0000 1410
    70 0000 0000                    00 0000 0000                70 0073 0000
    70 0000 0000                    02 0000 0400                06 0062 0174
    70 0000 0400                    00 0000 0000                71 0162 0174
    70 0000 0000    0020            31 0001 0001    0110        70 0000 0400    0200
    70 0000 0000                    42 1400 0001                31 0151 0224
    70 0000 0000                    70 0217 0112                70 0000 0211
    70 0000 0000                    42 1604 1033                31 0150 0224
    70 0000 0000                    31 1777 0141                70 0000 0211
    70 0000 0000                    42 1404 0000                31 0152 0222
    70 0000 0000                    07 0000 0141                31 0153 0223
    70 0000 0000                    35 0100 0104                31 0154 0224
    70 0000 0000    0030            30 0455 0000    0120        31 0001 0001    0210
    70 0000 0000                    05 0104 0105                31 0001 0001
    70 0000 0000                    31 0001 0001                42 1430 0011
    70 0000 0000                    31 0001 0001                42 1002 0223
    70 0000 0000                    31 0101 0126                40 0217 0005
    70 0000 0000                    31 0125 1000                42 1404 0000
    70 0000 0000                    00 0000 0000                70 0000 0400
    70 0000 0000                    71 0126 0130                20 0302 0030
    70 0000 0000    0040            71 1000 0126    0130        22 0613 0100    0220
    70 0000 0000                    31 0102 0133                27 0610 0000
    70 0000 0000                    31 0132 0631                21 1002 1000
    70 0000 0000                    00 0000 0000                31 0000 0000
    70 0000 0000                    71 0133 0135                00 0000 0000
    70 0000 0000                    71 0631 0133                72 0505 0224
    70 0000 0605                    31 0063 0103                72 0505 0225
    70 0000 0000                    31 0105 1000                00 0000 0000
    33 0000 0000    0050            42 1430 0011    0140        31 0246 0233    0230
    70 0000 0560                    00 0000 0000                31 0247 0162
    70 0000 0372                    40 1000 0400                70 0034 0233
    70 0000 0424                    06 0106 1000                07 0000 1776
    70 0000 0000                    71 0103 0141                70 0074 0240
    70 0000 0000                    42 1404 0000                02 0061 0233
    70 0000 0000                    31 0060 1000                71 0162 0233
    70 0000 0000                    70 0000 0400                70 0000 0400
    00 0000 0000    0060            27 1533 0200    0150        31 0244 0222    0240
    00 0000 0001                    26 1442 0600                31 0245 0223
    00 0000 0002                    70 0652 0400                31 0233 1770
    00 0000 0003                    30 1452 1300                70 0000 0211
    00 0000 0004                    27 0660 0000                27 1403 0100
    00 0000 0005                    70 0032 0201                24 0633 1000
    00 0000 0006                    70 0072 0203                07 0000 1776
    00 0000 0007                    70 0073 0205                00 0000 1774
```

```
OVERLAY 05

00 0000 0000    0250
72 0505 0250
72 0505 0251
72 0505 0252
72 0505 0253
72 0505 0254
72 0505 0255
72 0505 0256
72 0505 0257    0260
72 0505 0260
72 0505 0261
72 0505 0262
72 0505 0263
72 0505 0264
72 0505 0265
72 0505 0266
72 0505 0267    0270
72 0505 0270
72 0505 0271
72 0505 0272
72 0505 0273
72 0505 0274
72 0505 0275
72 0505 0276
72 0505 0277    0300
72 0505 0300
72 0505 0301
72 0505 0302
72 0505 0303
72 0505 0304
72 0505 0305
72 0505 0306
72 0505 0307    0310
72 0505 0310
72 0505 0311
72 0505 0312
72 0505 0313
72 0505 0314
72 0505 0315
72 0505 0316
72 0505 0317    0320



72 0505 0367    0370
72 0505 0370
72 0607 0605
31 0414 0607
06 0062 0520
70 0000 0400
00 0201 0500
00 0000 0005
```

OVERLAY 06

```
                                                00 0000 0053 0070       72 0505 0157 0160
                                                00 0000 0037            72 0505 0160
    70 0000 0646                                00 0000 0077            72 0505 0161
    70 0000 0472                                20 0012 0001            72 0505 0162
    70 0000 0660                                00 0201 0600            72 0505 0163
    70 0000 0667                                00 0001 0400            72 0505 0164
    70 0000 0501                                70 0000 0404            72 0505 0165
    70 0000 0523                                00 0000 0070            00 0000 0000
    70 0000 0000 0010                           00 0000 0000 0100       00 0000 1777 0170
    70 0000 0000                                70 0000 0560            37 1777 1777
    70 0000 0000                                72 0505 0101            00 0000 0000
    70 0000 0000                                72 0505 0102            00 0002 0002
    70 0000 0000                                72 0505 0103            07 0000 1401
    70 0000 0000                                72 0505 0104            00 0000 0000
    70 0000 0000                                72 0505 0105            00 0000 0000
    70 0000 0400                                72 0505 0106            00 0000 0000
    70 0000 0000 0020                           72 0505 0107 0110       06 0062 0201 0200
    70 0000 0000                                72 0505 0110            07 0000 1401
    70 0000 0000                                72 0505 0111            73 1402 0200
    70 0000 0000                                72 0505 0112            01 1402 0000
    70 0000 0000                                72 0505 0113            73 0000 0212
    70 0000 0000                                72 0505 0114            34 0000 0177
    70 0000 0000                                72 0505 0115            03 1401 1403
    70 0000 0000                                72 0505 0116            34 0000 0176
    70 0000 0000 0030                           72 0505 0117 0120       03 0177 0176 0210
    70 0000 0000                                72 0505 0120            73 0177 0214
    70 0000 0101                                72 0505 0121            31 0061 0175
    70 0000 0000                                72 0505 0122            70 0000 0215
    70 0000 0000                                72 0505 0123            31 0060 0175
    70 0000 0000                                72 0505 0124            31 0001 0001
    70 0000 0000                                72 0505 0125            31 0433 0172
    70 0000 0140                                72 0505 0126            37 0000 0000
    70 0000 0000 0040                           72 0505 0127 0130       34 1402 1404 0220
    70 0000 0000                                72 0505 0130            06 0173 0220
    70 0000 0000                                72 0505 0131            71 0172 0217
    70 0000 0000                                72 0505 0132            71 0175 0231
    70 0000 0000                                72 0505 0133            03 0061 0201
    70 0000 0000                                72 0505 0134            36 0170 0226
    70 0000 0000                                30 0000 1402            31 0171 0000
    70 0000 0000                                30 0040 1402            31 0174 0201
    70 0000 0000 0050                           07 0000 1775 0140       70 0000 0400 0230
    70 0000 0000                                70 0072 0146            07 0061 0201
    70 0000 0000                                30 0052 0000            70 0000 0225
    70 0000 0424                                05 0137 0152            70 0000 0560
    70 0000 0000                                70 0000 0151            72 0505 0233
    70 0000 0000                                00 0000 0000            72 0505 0234
    70 0000 0000                                11 0000 0000            72 0505 0235
    70 0000 0000                                30 0052 0000            72 0505 0236
    00 0000 0000 0060                           05 0136 0152 0150       72 0505 0237 0240
    00 0000 0001                                07 0000 1402
    00 0000 0002                                30 0000 1401            72 0505 0372
    00 0000 0003                                31 0060 1775            72 0505 0373
    00 0000 0004                                70 0000 0201            72 0505 0374
    00 0000 0005                                72 0505 0154            00 0201 0600
    00 0000 0006                                72 0505 0155            00 0000 0006
    00 0000 0007                                72 0505 0156            27 1002 1700 0400
```

OVERLAY 07

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0000  0010
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0315
70 0000 0145
70 0000 0400
70 0000 0126  0020
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000  0030
70 0000 0000
70 0000 0101
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0201
70 0000 0000  0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
31 1402 0142  0050
07 0000 1402
73 0000 0020
70 0000 0146
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0201 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
70 0000 0560
07 0000 1402
70 0072 0130
25 0140 0000
30 0463 0000
05 0137 0136
34 0000 0000
25 0140 0000  0110
30 0455 0000
05 0136 0136
34 0000 0000
25 0140 0000
30 0446 0000
05 0136 0136
31 0136 0135
06 0061 0117  0120
34 0000 0000
72 0122 0104
42 1434 0011
42 1002 0223
40 0133 0003
72 0126 0102
70 0000 0225
31 0135 0134  0130
70 0000 0104
00 0000 0000
20 0062 0006
00 0130 1200
00 0140 1200
10 0201 0000
10 0201 0000
00 0000 0012  0140
00 0000 0000
00 0000 0000
00 0000 0000
40 0000 0005
70 0000 0050
31 1775 0143
31 0060 0141
07 0000 0142  0150
30 0077 0142
01 0061 1005
07 0000 0142
30 0001 0142
02 1005 0143
73 0000 0200
73 0144 0165
70 0072 0174  01
22 0171 0142
02 0064 0143
06 0061 0141
70 0000 0150
26 0171 0142
06 0064 0143
02 0061 0141
70 0000 0150  0170
24 0000 0000
00 0000 0000
00 0000 0000
30 0052 0000
36 0415 0177
07 0000 0142
30 0000 0142
31 1775 0172  0200
31 1402 0173
31 0141 1775
31 0142 1402
72 0256 0020
31 0172 1775
31 0173 1402
02 0213 0260
31 0214 0261  0210
72 0256 0253
70 0000 0400
00 0010 0001
00 0002 0300
00 0000 0000
05 1000 0000
06 0000 0000
00 0002 0300  0220
00 0000 0012
00 0000 0000
00 0201 0000
00 0000 0000
30 0060 0222
13 0000 1775
34 0000 0220
07 0000 0220  0230
73 0221 0235
02 0221 0220
06 0061 0222
70 0000 0230
03 0221 0220
73 0000 0232
07 0000 0220
30 0046 0000  0240
05 0223 0224
07 0000 0222
30 0055 0000
05 0224 0224
07 0000 1775
70 0072 0251
06 0216 0224
```

OVERLAY 07

```
70 0000 0252  0250
06 0217 0224
31 0224 0261
42 1434 0011
42 1002 0223
40 0260 0001
70 0000 0400
00 0000 0000
20 0122 0012  0260
00 0000 0000
13 0000 0141
73 0142 0166
07 0141 0000
30 1201 0141
06 0061 0214
70 0000 0262
31 1001 0200  0270
31 1002 0201
00 0000 0000
00 0000 0000
00 0000 0000
31 1775 1004
31 1402 1003
31 1001 1402
31 1002 1775  0300
72 0212 0145
31 1003 1402
31 1004 1775
31 0270 1251
31 0271 1252
31 1275 1253
33 0000 0030
70 0000 1246  0310
06 0306 0260
70 0000 0400
00 0010 0001
00 0140 0014
06 0314 0133
06 0314 0260
70 0000 0400
72 0505 0317  0320
72 0505 0320
72 0505 0321
72 0505 0322
72 0505 0323
72 0505 0324
72 0505 0325
72 0505 0326
72 0505 0327  0330
72 0505 0330
72 0505 0331
72 0505 0332
72 0505 0333
72 0505 0334
72 0505 0335
72 0505 0336
72 0505 0337  0340
72 0505 0340
72 0505 0341
72 0505 0342
72 0505 0343
72 0505 0344
72 0505 0345
72 0505 0346
72 0505 0347  0350
72 0505 0350
72 0505 0351
72 0505 0352
72 0505 0353
72 0505 0354
72 0505 0355
72 0505 0356
72 0505 0357  0360
72 0505 0360
72 0505 0361
72 0505 0362
72 0505 0363
72 0505 0364
72 0505 0365
72 0505 0366
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0201 0700
00 0000 0007
```

OVERLAY 10

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0156
70 0000 0211  0010
70 0000 0213
70 0000 0215
70 0000 0341
70 0000 0177
70 0000 0152
70 0000 0154
70 0000 0400
70 0000 0165  0020
70 0000 0177
70 0000 0201
70 0000 0227
06 0064 0140
06 0130 0140
06 0064 0140
06 0130 0140
06 0064 0140  0030
70 0000 0141
06 0064 0140
06 0130 0140
06 0064 0140
06 0130 0140
06 0064 0140
70 0000 0131
70 0000 0203  0040
70 0000 0223
70 0000 0217
70 0000 0225
70 0000 0221
70 0000 0231
70 0000 0605
00 0000 0000
33 0000 0000  0050
70 0000 0560
70 0000 0161
70 0000 0424
70 0000 0116
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0211 0000
00 0001 0400
70 0000 0404
00 0000 0070
70 0000 0560  0100
70 0000 0560
42 1002 0000
41 1000 0376
70 0000 0104
42 1420 0010
42 1002 1704
41 1400 0376
70 0000 0137  0110
42 1420 0010
42 1007 0064
40 1400 0376
70 0000 0150
72 0054 0400
01 0125 0124
71 0124 0120
07 0000 0124  0120
30 0044 0000
05 0126 0124
70 0000 0135
00 0000 1704
00 0000 0055
00 0000 1704
00 0000 0300
00 0000 0574  0130
06 0127 0140
31 0140 0126
02 0140 0140
72 0123 0241
36 0553 0106
72 0110 0105
70 0000 0400
00 0000 0000  0140
06 0127 0140
31 0140 0126
02 0140 0140
72 0123 0115
34 0000 1776
36 0555 0112
72 0114 0111
70 0000 0400  0150
70 0000 0560
33 0000 0001
70 0000 0157
33 0000 0002
70 0000 0157
33 0000 0020
72 0657 0652
70 0000 0661  0160
72 0605 0607
31 0414 0607
06 0062 0520
70 0000 0400
07 0000 0402
70 0065 0400
31 0054 0175
33 0000 0000  0170
72 0054 0560
31 0175 0054
72 0402 0054
70 0000 0605
00 0000 0000
00 0000 0000
31 0060 0176
70 0000 0205  0200
31 0061 0176
70 0000 0205
31 0176 1772
70 0000 0400
33 0000 0010
72 0657 0652
70 0000 0670
70 0000 0560  0210
33 0000 0001
70 0000 0560
33 0000 0004
70 0000 0560
33 0000 0007
70 0000 0560
33 0000 0012
70 0000 0560  0220
33 0000 0013
70 0000 0560
33 0000 0014
70 0000 0560
33 0000 0015
70 0000 0560
33 0000 0016
00 0000 0000  0230
72 0240 0233
70 0000 1001
42 1400 0001
70 0217 0234
42 1603 0000
42 1604 1001
41 1000 0376
70 0000 0240  0240
72 0053 0115
34 0000 0367
72 0240 0233
70 0000 1250
70 0000 0560
72 0505 0245
72 0505 0246
```

OVERLAY 10

```
72 0505 0247  0250
72 0505 0250
72 0505 0251
72 0505 0252
72 0505 0253
72 0505 0254
72 0505 0255
72 0505 0256
72 0505 0257  0260
72 0505 0260
72 0505 0261
72 0505 0262
72 0505 0263
72 0505 0264
72 0505 0265
72 0505 0266
72 0505 0267  0270
72 0505 0270
72 0505 0271
72 0505 0272
72 0505 0273
72 0505 0274
72 0505 0275
72 0505 0276
72 0505 0277  0300
72 0505 0300
72 0505 0301
72 0505 0302
72 0505 0303
72 0505 0304
72 0505 0305
72 0505 0306
72 0505 0307  0310
72 0505 0310
72 0505 0311
72 0505 0312
72 0505 0313
72 0505 0314
72 0505 0315
72 0505 0316
72 0505 0317  0320
72 0505 0320
72 0505 0321
72 0505 0322
72 0505 0323
72 0505 0324
72 0505 0325
72 0505 0326
72 0505 0327  0330
72 0505 0330
72 0505 0331
72 0505 0332
72 0505 0333
72 0505 0334
72 0505 0335
72 0505 0336
72 0505 0337  0340
72 0505 0340
72 0505 0341
72 0505 0342
72 0505 0343
72 0505 0344
72 0505 0345
72 0505 0346
72 0505 0347  0350
72 0505 0350
72 0505 0351
72 0505 0352
72 0505 0353
72 0505 0354
72 0505 0355
72 0505 0356
72 0505 0357  0360
72 0505 0360
72 0505 0361
72 0505 0362
72 0505 0363
72 0505 0364
72 0505 0365
72 0505 0366
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0211 0000
00 0000 0010
```

OVERLAY 17

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0000  0010
70 0000 0263
70 0000 0000
70 0000 0263
70 0000 0326
70 0000 0000
70 0000 0000
70 0000 0400
70 0000 0331  0020
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000  0030
70 0000 0000
70 0000 0273
70 0000 0306
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0345
70 0000 0000  0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0605
70 0000 0000
33 0000 0000  0050
70 0000 0560
70 0000 0334
70 0000 0424
70 0000 0151
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0211 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
42 1410 0017
31 0060 1000
42 1000 1211
41 1000 0777
70 0000 0400
42 1410 0017
31 0060 1000
42 1000 1271  0110
40 1000 0777
70 0000 0400
72 0657 0652
73 0000 0123
34 0000 1001
36 0571 0120
42 1420 0007
42 1000 0202  0120
41 1001 0376
70 0000 0400
07 0000 0676
70 0000 0115
07 0000 1377
72 0657 0652
73 0000 0136
34 0000 1001  0130
36 0571 0133
42 1420 0007
42 1000 0222
40 1001 0376
70 0000 0400
07 0000 0676
70 0000 0130
00 0000 0000  0140
00 0000 0000
72 0613 0610
05 0556 0000
36 0555 0147
31 0060 1400
42 1420 0010
42 1002 0000
41 1400 0100  0150
70 0000 0400
07 0000 1477
72 0613 0610
05 0556 0000
36 0555 0157
42 1420 0010
42 1006 0000
40 1400 0100  0160
70 0000 0400
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0007  0170
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0036
33 0000 0000
00 0000 0500
70 0000 0560
06 0061 0170  0200
72 0122 0113
31 0067 0173
31 0001 0001
06 0061 0173
36 0072 0206
03 0263 1000
36 0417 0210
03 0175 0000  0210
73 0060 0230
73 0176 0214
70 0000 0230
34 0000 0172
07 0061 0210
36 0417 0217
03 0177 0000
73 0000 0222  0220
70 0000 0230
07 0000 0172
72 0151 0142
06 0061 0171
34 0000 1477
70 0000 0361
70 0000 0264
03 0174 0173  0230
73 0060 0204
72 0135 0325
03 0352 0170
73 0060 0200
31 0001 0001
03 0061 0176
72 0151 0142
71 1477 0242  0240
70 0000 0244
72 0161 0152
70 0000 0240
42 1410 0017
42 1000 1271
42 1006 1411
70 0000 0353
```

OVERLAY 17

```
70 0000 0353  0250
73 0060 0254
72 0161 0152
70 0000 0247
72 0161 0152
70 0000 0320
72 0402 0404
70 0000 0102
00 0000 0000  0260
03 0260 1010
03 0260 1036
00 0000 1000
31 0257 0260
31 0261 0266
03 0260 1001
73 0000 0312
06 0061 0266  0270
73 0262 0266
03 0263 0260
36 0417 0275
72 0344 0336
34 0000 0000
07 0000 0206
36 0417 0301
07 0000 0260  0300
34 0000 0000
03 0256 1473
73 0000 0310
06 0061 0172
72 0227 0223
70 0000 0302
70 0000 0264
31 0307 0227  0310
70 0000 0230
02 0062 0260
70 0000 0265
72 0505 0375
00 0000 0000
72 0505 0200
34 0000 1375
33 0000 0000  0320
72 0122 0113
31 0171 1200
72 0135 0125
70 0000 0400
31 0314 0315
31 0317 0332
06 0061 0315
73 0316 0332  0330
70 0000 0334
34 0000 0000
71 0332 0327
31 0177 1200
70 0000 0125
05 0061 0000
36 0417 0340
31 0177 0000  0340
70 0000 0343
70 0000 0312
07 0175 0171
70 0000 0275
42 1410 0017
42 1000 1231
42 1000 1231
42 1000 1231  0350
70 0000 0200
00 0000 0015
31 0063 0370
72 0105 0101
70 1034 0250
71 0370 0250
42 1000 1411
70 0000 0103  0360
31 0063 0370
72 0112 0106
70 1022 0363
70 0205 0227
71 0370 0227
42 1000 1411
70 0000 0110
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0211 0700
00 0000 0017
```

OVERLAY 20

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0136 0010
70 0000 0000
70 0000 0135
70 0000 0000
70 0000 0163
70 0000 0102
70 0000 0116
70 0000 0400
70 0000 0125 0020
70 0000 0137
70 0000 0141
70 0000 0131
70 0000 0130
70 0000 0132
70 0000 0143
70 0000 0145
70 0000 0147 0030
70 0000 0151
70 0000 0153
70 0000 0155
70 0000 0000
70 0000 0000
70 0000 0157
70 0000 0161
70 0000 0000 0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000 0050
70 0000 0000
70 0000 0000
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000 0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053 0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000 0100
70 0000 0560
31 0433 0464
07 0000 1775
31 1774 1775
34 0000 1774
07 0000 1402
31 1401 1402
34 0000 1401 0110
06 0062 0106
06 0434 0107
06 0062 0110
71 0464 0106
70 0000 0400
31 0433 0464
31 1375 1774
31 1002 1401 0120
06 0434 0120
71 0464 0120
70 0000 0400
70 0000 0560
33 0000 0010
72 0657 0652
70 0000 0661
71 1775 0400 0130
70 0000 0605
07 0000 1402
73 0060 0605
70 0000 0400
70 0000 0560
33 0000 0004
70 0000 0560
72 0505 0137 0140
72 0505 0140
72 0505 0141
72 0505 0142
72 0505 0143
72 0505 0144
72 0505 0145
72 0505 0146
72 0505 0147 0150
72 0505 0150
72 0505 0151
72 0505 0152
72 0505 0153
72 0505 0154
72 0505 0155
72 0505 0156
72 0505 0157 0160
72 0505 0160
72 0505 0161
72 0505 0162
72 0505 0163
72 0505 0164
72 0505 0165
72 0505 0166
72 0505 0167 0170
72 0505 0170
72 0505 0171
72 0505 0172
72 0505 0173
72 0505 0174
72 0505 0175
72 0505 0176
72 0505 0177 0200
72 0505 0200
72 0505 0201
72 0505 0202
72 0505 0203
72 0505 0204
72 0505 0205
72 0505 0206
72 0505 0207 0210
72 0505 0210
72 0505 0211
72 0505 0212
72 0505 0213
72 0505 0214
72 0505 0215
72 0505 0216
72 0505 0217 0220
72 0505 0367 0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0221 0000
00 0000 0020
```

OVERLAY 21

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0000 0010
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0400
70 0000 0000 0020
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000 0030
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0310
70 0000 0143
70 0000 0000 0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0605
70 0000 0000
33 0000 0000 0050
70 0000 0560
70 0000 0372
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000 0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053 0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0221 0100
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000 0100
00 0000 0000
37 1777 1777
60 0000 0000
45 0525 0525
01 0525 0525
00 0421 0104
40 0055 1013
00 0006 1001 0110
00 0312 0312
00 0000 0000
31 0060 1002
31 0102 1001
00 0000 0000
31 0102 1401
05 1001 1001
05 1002 1002 0120
25 0102 0000
25 0103 0000
00 0000 0312
00 0002 0000
00 0000 0000
00 0000 0000
00 0000 0000
31 0433 0464 0130
07 0000 1402
30 0002 1402
06 0062 0131
06 0062 0132
71 0464 0131
70 0000 0136
00 0000 0000
00 0000 0000 0140
00 0000 0000
00 0000 0000
72 0143 0257
70 0000 0400
07 1775 0061
34 0000 0112
72 0136 0130
31 0113 0131 0150
31 0114 0132
72 0136 0130
31 0116 0131
31 0145 0132
31 0001 0001
72 0136 0130
31 0001 0001
31 0433 0464 0160
31 0062 0115
31 0121 0165
31 0122 0170
26 1402 1401
25 0102 0000
05 1002 1002
26 1402 1401
25 0103 0000 0170
05 1001 1001
06 0124 0165
06 0124 0170
71 0115 0164
06 0434 0164
06 0434 0166
06 0434 0167
06 0434 0171 0200
71 0464 0161
31 0433 0464
31 1001 1401
31 1002 1402
06 0434 0203
06 0434 0204
71 0464 0203
70 0000 0217 0210
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
31 0433 0464
27 1401 1402 0220
30 0041 1002
27 1402 1402
34 0000 1001
27 1401 1401
01 1001 1001
06 0434 0220
06 0062 0221
06 0434 0222 0230
06 0062 0223
06 0434 0224
06 0434 0225
71 0464 0220
02 0111 0220
02 0111 0222
02 0111 0224
02 0111 0225 0240
02 0123 0223
02 0123 0221
02 0111 0203
02 0111 0204
72 0210 0202
71 0112 0217
02 1775 1775
```

OVERLAY 21

```
70 0000 0400  0250
00 0000 0000
72 0505 0251
72 0505 0252
72 0505 0253
72 0505 0254
72 0505 0255
31 0433 0464
07 0000 1775  0260
73 0060 0263
70 0000 0276
11 0000 0000
73 0277 0266
07 0000 0277
30 0052 0000
05 0300 0271
07 0000 1402  0270
30 0000 1402
06 0062 0270
06 0062 0271
71 0464 0270
31 0060 1775
70 0000 0145
00 0000 0031
30 0000 1402  0300
00 0000 0000
77 1777 1777
26 1402 1402
00 0001 0000
00 0000 0000
00 0000 0000
00 0000 0000
72 0276 0143  0310
26 0302 0103
26 0302 0104
26 0302 0107
02 0304 0132
72 0136 0130
31 0113 0131
31 0114 0132
72 0136 0130  0320
31 0433 0464
31 0121 0325
31 0066 0115
26 1402 1001
25 0102 0000
05 1002 1002
06 0304 0325
71 0115 0324  0330
06 0434 0324
06 0434 0326
71 0464 0322
31 0433 0464
07 0000 1002
30 0001 0000
05 0103 1402
06 0062 0335  0340
06 0062 0337
71 0464 0335
31 1775 0112
70 0000 0373
31 0433 0464
31 0303 0347
26 1402 1402
06 0434 0347  0350
71 0464 0347
06 1775 1775
71 0112 0371
70 0000 0400
00 0000 0000
07 0000 1402
30 0041 1402
31 0433 0464  0360
07 0000 1402
70 0071 0345
06 0062 0361
71 0464 0361
02 0061 1775
31 0356 0131
31 0357 0132
72 0136 0130  0370
31 0356 0361
70 0000 0360
31 0061 1775
70 0000 0360
70 0000 0400
00 0221 0100
00 0000 0021
```

OVERLAY 22

```
00 0000 0000
70 0000 0472
70 0000 0660
70 0000 0667
00 0000 0000
31 0032 0007
07 0000 0063  0010
75 0000 0011
07 0000 0062
75 0000 0013
31 0043 0464
31 1400 0045
07 0000 0045
30 0023 0000
72 0053 0050  0020
07 0000 0045
30 0015 0000
72 0053 0050
07 0000 0045
30 0006 0000
72 0053 0050
06 0042 0015
71 0464 0015  0030
71 0044 0010
70 0000 0400
00 0000 0000
00 0000 0000
00 0000 0000
70 0000 0007
07 0000 0063
75 0000 0040  0040
70 0000 0251
00 0001 0000
00 0000 0013
00 0000 0011
00 0000 0000
00 0000 0077
00 0000 0000
37 0046 0060  0050
73 0000 0054
75 0000 0052
70 0000 0424
33 0000 0016
70 0000 0052
00 0000 0000
70 0000 0661
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0221 0200
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
00 0000 0000
07 0000 1050
00 0000 0025
00 0000 0002
00 0000 0013
00 0000 0014
00 0000 0012
00 0000 0000  0110
05 1056 0441
40 0022 0656
00 0000 0000
00 0000 0000
00 0000 0067
00 0000 0070
07 1777 1777
31 0104 1050  0120
31 0104 1036
31 0104 1024
31 0107 1046
31 0107 1034
31 0102 0127
31 0103 0464
07 0000 1050
75 0000 0130  0130
02 0061 0127
71 0464 0127
70 0000 0000
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0020
00 0000 0000  0140
12 1252 1252
06 0631 1146
00 0000 0000
31 0060 0113
31 0060 0114
07 0110 0111
30 1257 0110
73 0000 0164  0150
70 0072 0162
06 0061 0113
06 0112 0110
70 0032 0152
30 0052 0110
31 0001 0001
70 0000 0164
06 0061 0113  0160
02 0112 0110
73 0112 0160
30 0052 0110
70 0000 0360
31 0117 0114
06 0110 0114
27 0110 0110
30 0041 0140  0170
05 0114 0114
27 0141 0140
25 0110 0140
30 0042 0140
05 0114 0114
26 0110 0140
05 0114 0114
27 0140 0110  0200
25 0142 0000
30 0042 0000
05 0114 0114
30 0042 0114
70 0000 0367
31 0001 0001
70 0000 0000
31 0117 1001  0210
31 0060 1377
02 0061 0211
71 1001 0211
31 1775 0110
72 0207 0144
07 0000 0113
70 0032 0235
31 0106 1046  0220
70 0000 0236
00 0000 0000
31 0060 0143
06 0061 0143
02 0136 0140
73 0000 0232
70 0032 0224
06 0136 0140  0230
03 0061 0143
70 0000 0000
00 0000 0000
00 0000 0000
31 0105 1046
11 0060 0140
31 0433 0136
72 0232 0223  0240
05 0137 1045
31 0107 0136
72 0232 0223
05 0137 1044
07 0137 0140
34 0000 1043
70 0000 0000
```

OVERLAY 22

```
00 0000 0000 0250
72 0247 0210
31 0116 1035
31 1046 1034
31 1045 1033
31 1044 1032
31 1043 1031
31 1774 0110
31 0114 0135 0260
31 0001 0001
72 0247 0215
31 0115 1047
72 0133 0350
31 0001 0001
31 0414 0251
31 0001 0001
31 0001 0001 0270
31 0433 0342
27 0114 1401
31 0105 1047
70 0032 0276
31 0106 1047
11 0000 0140
06 0062 0272
31 0316 0333 0300
72 0341 0322
27 0135 1402
31 0105 1035
70 0032 0306
31 0106 1035
11 0000 0140
31 0317 0333
72 0341 0322 0310
06 0062 0302
72 0133 0120
71 0342 0272
70 0000 0400
00 0000 0000
05 0137 0145
05 0137 1033
03 0314 1464 0320
00 0000 0000
31 0065 0315
31 0320 0321
31 0060 0143
06 0061 0143
02 0321 0140
70 0032 0325
72 0000 0344 0330
06 0321 0140
02 0061 0143
05 0137 0000
70 0000 0355
02 0061 0333
71 0315 0324
31 0001 0001
31 0001 0001 0340
70 0000 0000
00 0000 0000
00 0000 0000
07 0000 0143
70 0000 0333
00 0000 0000
70 0000 0056
31 0104 1050 0350
31 0104 1042
31 0104 1027
31 0063 1026
70 0000 0125
27 0320 0321
05 0061 0321
70 0000 0335
31 0060 0347 0360
13 0000 0110
73 0111 0165
07 0110 0000
30 1201 0110
06 0061 0347
70 0000 0361
71 0347 0371
70 0000 0206 0370
13 0000 0114
25 0114 0114
70 0000 0367
72 0505 0373
72 0505 0374
00 0221 0200
00 0000 0022
```

OVERLAY 23

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0205  0010
70 0000 0217
70 0000 0224
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0200
70 0000 0400
70 0000 0212  0020
70 0000 0227
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000  0030
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0224
70 0000 0205
70 0000 0200
70 0000 0113
70 0000 0000  0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0605
70 0000 0000
33 0000 0000  0050
70 0000 0560
70 0000 0372
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
70 0000 0560
27 1402 1002
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0031
30 0000 1401
30 0000 0104  0110
07 0000 1401
00 0000 0000
31 0433 0464
42 1410 0016
31 0060 1000
31 0114 1774
70 0000 0174
31 0433 0103  0120
31 0102 0123
31 0060 0104
27 1402 1002
30 0007 0000
05 0104 0104
06 0434 0123
71 0103 0123
07 0000 0104  0130
30 0077 0104
05 1774 0000
01 1775 0000
01 1375 0000
01 0067 0105
70 0032 0156
72 0167 0163
05 0107 0145  0140
03 0464 0433
34 0000 0103
31 0111 0144
07 0000 1401
30 0000 1401
06 0062 0144
06 0062 0145
71 0103 0144  0150
02 0105 1774
31 0104 1401
06 0062 0152
71 0464 0117
70 0000 0172
72 0167 0163
05 0110 0161
07 0000 0104  0160
30 0000 0104
70 0000 0152
13 0105 0106
73 0060 0170
13 0000 0105
30 0052 0000
70 0000 0000
13 0000 0106  0170
70 0000 0166
31 0001 0001
70 0000 0400
42 1000 1211
41 1000 0377
70 0000 0120
00 0000 0000
31 0060 1001  0200
31 0203 0175
70 0000 0113
41 1001 0376
00 0000 0000
31 0433 0464
31 0114 1774
31 0001 0001
72 0117 0120  0210
31 0433 0204
31 1004 1002
06 0434 0212
71 0204 0212
02 0223 0212
31 1001 1312
06 0222 0216
72 0155 0120  0220
70 0000 0400
00 0002 0000
00 0312 0312
31 0224 1713
31 1712 1401
02 0232 0225
06 0233 0225
71 1713 0225  0230
70 0000 0234
00 0002 0000
00 0000 0002
07 0000 1775
34 0000 0000
07 0000 1774
34 1774 1775
70 0000 0400  0240
72 0505 0240
72 0505 0241
72 0505 0242

70 0000 0400
00 0221 0300
00 0000 0023
27 1002 1700  0400
```

OVERLAY 24

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0110 0010
70 0000 0127
72 0012 0240
70 0000 0400
31 0032 0020
31 0034 0464
31 0035 0017
07 0000 1001
30 0000 1001 0020
06 0061 0017
06 0061 0020
71 0464 0017
70 0000 0265
00 0000 0000
31 0033 0020
72 0024 0015
70 0000 0400 0030
00 0000 0000
30 0001 1001
30 0041 1001
00 0000 0720
07 0000 1001
70 0000 0000
70 0000 0000
70 0000 0000 0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000 0050
70 0000 0000
70 0000 0000
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000 0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053 0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0221 0000
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000 0100
00 0000 0000
03 1401 0370
00 0000 1000
04 0000 0000
05 0104 1002
02 0000 0400
31 0060 1377
31 0110 1001 0110
31 0060 1377
71 0111 0113
71 0101 0111
31 0107 0111
31 0105 1375
31 0106 1001
72 0055 0400
31 1375 0121 0120
00 0000 0000
06 0062 1375
42 1434 0011
42 1000 0223
40 1001 0140
70 0000 0116
31 0132 1151
72 0055 0400 0130
30 1012 0000
34 1146 1145
07 0000 1002
70 0027 0155
01 0104 0000
30 1012 0000
34 1150 1147
01 1145 1147 0140
25 1147 0000
34 1147 0000
02 1146 1150
25 1150 0000
30 0005 0000
05 1147 0000
73 1151 0152
06 0062 0133 0150
70 0000 0133
34 0000 1151
31 0133 1152
70 0000 0150
07 0000 1152
36 0417 0162
07 0062 1152
34 0000 0161 0160
00 0000 0000
34 0000 0000
06 0062 0162
06 0062 0161
01 0062 0000
73 0133 0161
31 0171 0133
70 0000 0123 0170
07 0000 1002
00 0000 0400
37 1777 1777
00 0002 0000
00 0000 0000
00 0000 0060
31 1002 0175
31 1002 0175 0200
07 0000 0175
73 0000 0207
31 0000 0000
02 0434 0203
06 0174 0202
70 0000 0201
07 0000 0203
36 0417 0211 0210
31 0175 0000
31 0001 0001
31 0001 0001
07 0000 0200
36 0415 0202
36 0415 0203
05 0174 0000
36 0415 0200 0220
30 0012 0000
36 0417 0203
71 0464 0200
70 0000 0231
31 0173 1000
31 0177 0200
31 0176 0464
70 0000 0212 0230
31 0060 1000
70 0000 0232
21 0103 1001
07 0000 1000
73 1401 0347
00 0001 0000
07 0000 1061
72 0232 0225 0240
31 0176 0464
31 1002 0175
07 0000 0175
37 0417 0060
01 0103 0000
21 0103 1002
07 0000 0175
```

OVERLAY 24

```
37 0415 0060  0250
30 0012 0000
01 0103 0000
21 0103 1001
06 0174 0242
06 0062 0246
06 0062 0253
71 0464 0242
07 0000 0233  0260
34 0000 0253
05 0061 0246
31 0177 0242
70 0000 0014
31 0433 0464
31 1401 0370
31 1402 0371
31 1402 0374  0270
31 0102 0364
31 0237 0300
31 0370 0372
31 0371 0373
31 0374 0375
31 0364 0363
31 0235 0301
00 0000 0000  0300
73 1401 0347
02 0174 0301
70 0000 0300
07 0000 0301
31 0001 0001
36 0415 0310
05 0432 0311
31 0000 0370  0310
00 0000 0000
07 0061 0300
34 0000 0314
00 0000 0000
34 0000 0374
03 0374 0371
34 0000 0367
03 0372 0370  0320
34 0000 0366
03 0375 0373
01 0367 0000
70 0000 0353
07 0000 0301
37 0415 0363
34 0000 0364
31 0363 0334  0330
07 0236 0334
30 0012 0000
36 0417 0341
00 0000 0000
25 0366 0000
30 0052 0000
05 0367 0365
31 0001 0001  0340
02 0365 0000
07 0352 0334
73 0364 0356
02 0062 0300
73 0234 0026
70 0000 0273
01 0172 0000
73 0000 0344  0350
70 0000 0304
00 0003 0000
30 0012 0000
21 0366 0366
70 0000 0325
06 0174 0334
70 0000 0331
72 0505 0357  0360
72 0505 0360
72 0505 0361
72 0505 0362
72 0505 0363
72 0505 0364
72 0505 0365
72 0505 0366
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0221 0400
00 0000 0024
```

OVERLAY 25

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0205 0010
70 0000 0217
70 0000 0224
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0200
70 0000 0400
70 0000 0212 0020
70 0000 0227
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000 0030
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0113
70 0000 0000 0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0605
70 0000 0000
33 0000 0000 0050
70 0000 0560
70 0000 0372
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000 0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053 0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000 0100
70 0000 0560
27 1402 1002
00 0000 0000
00 0000 0000
00 0000 0000
00 0000 0031
30 0000 1401
30 0000 0104 0110
07 0000 1401
00 0000 0000
31 0433 0464
42 1410 0016
31 0060 1000
31 0114 1774
70 0000 0174
31 0433 0103 0120
31 0102 0123
31 0060 0104
27 1402 1002
30 0007 0000
05 0104 0104
06 0434 0123
71 0103 0123
07 0000 0104 0130
30 0077 0104
05 1774 0000
01 1775 0000
01 1375 0000
01 0067 0105
70 0032 0156
72 0167 0163
05 0107 0145 0140
03 0464 0433
34 0000 0103
31 0111 0144
07 0000 1401
30 0000 1401
06 0062 0144
06 0062 0145
71 0103 0144 0150
02 0105 1774
31 0104 1401
06 0062 0152
71 0464 0117
70 0000 0172
72 0167 0163
05 0110 0161
07 0000 0104 0160
30 0000 0104
70 0000 0152
13 0105 0106
73 0060 0170
13 0000 0105
30 0052 0000
70 0000 0000
13 0000 0106 0170
70 0000 0166
31 0001 0001
70 0000 0400
42 1000 1211
41 1000 0377
70 0000 0120
00 0000 0000
31 0060 1400 0200
42 1410 0016
42 1000 1271
40 1400 0376
70 0000 0400
31 0060 1400
42 1410 0016
42 1000 1211
41 1400 0376 0210
70 0000 0400
31 0060 1000
42 1410 0016
42 1000 1271
40 1000 0377
70 0000 0400
31 0060 1000
42 1410 0016 0220
42 1000 1211
41 1000 0377
70 0000 0400
42 1410 0016
42 1002 1211
70 0000 0400
42 1410 0016
42 1002 1411 0230
70 0000 0400
70 0000 0560
72 0505 0232
72 0505 0233
72 0505 0234

72 0505 0367 0370
72 0505 0370
72 0607 0605
31 0414 0607
06 0062 0520
70 0000 0400
00 0221 0500
00 0000 0025
```

OVERLAY 30

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0136  0010
70 0000 0000
70 0000 0135
70 0000 0000
70 0000 0163
70 0000 0102
70 0000 0116
70 0000 0400
70 0000 0125  0020
70 0000 0137
70 0000 0141
70 0000 0131
70 0000 0130
70 0000 0132
70 0000 0143
70 0000 0145
70 0000 0147  0030
70 0000 0151
70 0000 0153
70 0000 0155
70 0000 0000
70 0000 0000
70 0000 0157
70 0000 0301
70 0000 0000  0040
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000  0050
70 0000 0000
70 0000 0000
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
70 0000 0560
31 0433 0464
07 0000 1775
31 1774 1775
34 0000 1774
07 0000 1402
31 1401 1402
34 0000 1401  0110
06 0062 0106
06 0434 0107
06 0062 0110
71 0464 0106
70 0000 0400
31 0433 0464
31 1375 1774
31 1002 1401  0120
06 0434 0120
71 0464 0120
70 0000 0400
70 0000 0560
33 0000 0010
72 0657 0652
70 0000 0661
71 1775 0400  0130
70 0000 0605
07 0000 1402
73 0060 0605
70 0000 0400
70 0000 0560
33 0000 0004
70 0000 0560
72 0505 0137  0140
72 0505 0140
72 0505 0141
72 0505 0142
72 0505 0143
72 0505 0144
72 0505 0145
72 0505 0146
72 0505 0147  0150
72 0505 0150
72 0505 0151
72 0505 0152
72 0505 0153
72 0505 0154
72 0505 0155
72 0505 0156
72 0505 0157  0160
72 0505 0160
72 0505 0161
72 0505 0162
72 0505 0163
72 0505 0164
72 0505 0165
72 0505 0166
72 0505 0167  0170
72 0505 0170
72 0505 0171
72 0505 0172
72 0505 0173
72 0505 0174
72 0505 0175
72 0505 0176
37 1777 1777  0200
30 0077 0231
34 0000 0232
27 0231 0243
05 0243 0233
03 0233 0200
21 0233 0244
25 0244 0245
25 0234 0000  0210
05 0235 0000
25 0245 0000
05 0236 0000
25 0245 0000
05 0237 0000
25 0245 0000
05 0240 0000
25 0245 0000  0220
05 0241 0000
25 0245 0000
05 0242 0000
25 0245 0000
25 0244 0000
05 0244 0233
70 0000 0000
00 0000 0000  0230
00 0000 0000
00 0000 0000
02 0210 1042
02 0210 1042
02 0730 1166
02 1642 1643
03 1070 1616
04 1111 0222  0240
06 0631 1146
12 1252 1253
20 0000 0000
00 0000 0000
00 0000 0000
77 1777 1777
26 0271 0060
```

OVERLAY 30

```
31 0001 0001  0250
06 0062 0252
07 0000 1400
72 0227 0201
03 0232 1775
25 0247 1375
30 1077 1375
70 0000 0321
30 0052 0000  0260
36 0415 0265
07 0000 1375
30 0001 1375
03 0233 0060
30 0000 0000
05 1375 1402
02 0061 1374
13 0000 1374  0270
34 0000 1002
73 0246 0274
34 0000 0246
06 0062 0271
06 0062 0266
71 0464 0251
31 0246 1775
70 0000 0300  0300
31 0433 0464
72 0300 0250
31 0433 0464
03 1002 1775
30 0052 0000
36 0415 0310
07 0000 1402
30 0000 1402  0310
06 0062 0307
06 0062 0310
06 0320 0304
71 0464 0304
72 0302 0400
70 0000 0400
00 0000 0031
00 0002 0000  0320
73 0317 0323
07 0000 0317
01 0317 1374
70 0000 0260
72 0505 0324
72 0505 0325
72 0505 0326
72 0505 0327  0330
72 0505 0330
72 0505 0331
72 0505 0332
72 0505 0333
72 0505 0334
72 0505 0335
72 0505 0336
72 0505 0337  0340
72 0505 0340
72 0505 0341
72 0505 0342
72 0505 0343
72 0505 0344
72 0505 0345
72 0505 0346
72 0505 0347  0350
72 0505 0350
72 0505 0351
72 0505 0352
72 0505 0353
72 0505 0354
72 0505 0355
72 0505 0356
72 0505 0357  0360
72 0505 0360
72 0505 0361
72 0505 0362
72 0505 0363
72 0505 0364
72 0505 0365
72 0505 0366
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0231 0000
00 0000 0030
```

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0102
70 0000 0110
70 0000 0232  0010
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400  0020
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400  0030
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0267
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400  0040
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0400
70 0000 0605
70 0000 0400
33 0000 0000  0050
70 0000 0560
70 0000 0372
70 0000 0424
70 0000 0000
70 0000 0000
70 0000 0000
70 0000 0000
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0400
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
70 0000 0560
31 0216 0225
31 0217 0226
31 0063 0231
72 0255 0242
72 0205 0132
70 0000 0245
31 0215 0225  0110
31 0060 0226
31 0063 0231
70 0000 0126
72 0205 0132
70 0000 0126
72 0427 0423
31 0220 0225
31 0221 0226  0120
31 0063 0231
72 0205 0133
07 0061 0150
71 0241 0133
70 0000 0234
31 0256 0253
72 0255 0245
00 0000 0000  0130
70 0000 0114
03 0061 0253
36 0417 0150
42 1430 0011
72 0262 0257
31 0060 0223
42 1002 0023
40 0222 0001  0140
06 0207 0222
73 0206 0144
01 0210 0222
34 0000 0531
31 0211 0223
31 0060 0224
71 0231 0157
07 0000 0000  0150
30 1427 0000
30 0444 0000
30 1443 0000
30 0446 0000
05 0212 0224
70 0000 0161
07 0000 0150
30 1412 0000  0160
33 0000 0000
30 1441 0000
30 0446 0000
05 0213 0227
33 0000 0000
30 1443 0000
30 0443 0000
30 1443 0000  0170
30 0444 0000
30 1443 0000
30 0446 0000
05 0214 0230
71 0231 0202
31 0227 0225
31 0230 0226
31 0061 0231  0200
70 0000 0161
42 1002 0023
40 0222 0006
71 0231 0134
70 0000 0000
21 1522 0352
00 0140 0014
01 1300 0330  0210
00 1010 0100
00 0201 0000
00 0001 0000
10 0201 0000
21 1560 0000
24 0553 0200
22 0613 0300
26 0442 1400  0220
27 0613 1000
20 0222 0022
72 0505 0222
72 0505 0223
24 0553 0200
22 0613 0300
72 0505 0226
72 0505 0227  0230
00 0000 0003
31 0062 0466
70 0000 0116
36 0417 0150
72 0427 0423
01 0061 0241
07 0000 0150
70 0000 0117  0240
00 0000 0000
31 0062 0466
72 0427 0423
36 0417 0253
72 0427 0423
31 0061 0465
30 0441 0000
```

```
OVERLAY 34

31 0063 0466  0250
72 0427 0425
71 0465 0247
34 0000 0000
06 0061 0253
70 0000 0000
34 0000 0130
03 0017 0530
73 0000 0263  0260
31 0266 0144
70 0000 0000
31 0531 0222
70 0000 0262
70 0000 0145
70 0000 0560
33 0000 0032
70 0000 0560  0270
72 0505 0270
72 0505 0271
72 0505 0272
72 0505 0273
72 0505 0274
72 0505 0275
72 0505 0276


72 0505 0367  0370
72 0505 0370
72 0607 0605
31 0414 0607
06 0062 0520
70 0000 0400
00 0231 0400
00 0000 0034
```

OVERLAY 35

```
                                                00 0000 0053  0070        06 0432 1374  0160
                                                00 0000 0037              42 1001 0223
                    70 0000 0646                00 0000 0077              06 0064 1374
                    70 0000 0472                20 0012 0001              42 1000 0223
                    70 0000 0660                00 0231 0500              00 0000 0000
                    70 0000 0667                00 0001 0400              72 0505 0164
                    70 0000 0501                7( 0000 0404              72 0505 0165
                    70 0000 0523                00 0000 0070              00 0000 0000
                    70 0000 0170  0010          00 0000 0000  0100        42 1444 0013  0170
                    70 0000 0150                00 0000 0000              70 0220 0171
                    70 0000 0000                70 0000 0000              70 0017 0171
                    70 0000 0000                72 0403 0401              70 0056 0171
                    70 0000 0000                00 0000 0000              31 0261 0257
                    70 0000 0310                31 0001 0001              71 0257 0175
                    70 0000 0000                31 0001 0001              31 0176 1000
                    70 0000 0400                72 0420 0400              31 0260 0200
                    70 0000 0140  0020          31 0103 0420  0110        31 0060 1400  0200
                    70 0000 0000                33 0000 0000              71 0200 0202
                    70 0000 0000                75 1000 0112              71 1000 0200
                    70 0000 0000                36 0072 0102              42 1001 0104
                    70 0000 0312                31 0001 0001              41 1000 0050
                    70 0000 0314                31 0060 0466              31 0256 0257
                    70 0000 0316                72 0427 0423              71 0257 0206
                    70 0000 0320                34 0000 0101              31 1001 0254
                    70 0000 0322  0030          42 1400 0002  0120        07 0000 0251  0210
                    70 0000 0000                70 0217 0121              37 0254 0250
                    70 0000 0334                42 1603 1274              73 0000 0242
                    70 0000 0324                42 1604 1274              31 0247 0217
                    70 0000 0326                31 0101 1777              31 0001 0001
                    70 0000 0330                31 0102 1777              31 0001 0001
                    70 0000 0000                42 1404 1401              36 0000 0000
                    70 0000 0332                42 1430 0011              07 0000 1001
                    70 0000 0000  0040          42 1002 0223  0130        30 1417 0254  0220
                    70 0000 0000                40 0135 0001              35 0255 0000
                    70 0000 0000                42 1404 0000              73 0000 0174
                    70 0000 0000                70 0000 0400              30 0437 0000
                    70 0000 0000                00 0000 0000              30 0443 0254
                    70 0000 0000                27 1212 1721              31 0001 0001
                    70 0000 0605                00 0000 0000              30 1455 0000
                    70 0000 0105                00 0000 0000              35 0255 0000
                    33 0000 0000  0050          31 0001 0001  0140        73 0000 0174  0230
                    70 0000 0560                42 1400 0001              30 0437 0000
                    70 0000 0336                70 0217 0142              03 0254 0254
                    70 0000 0424                42 1603 1120              73 0000 0233
                    70 0000 0000                31 0160 1777              07 0000 0253
                    70 0000 0000                42 1603 1033              37 0254 0252
                    70 0000 0000                31 0161 1777              73 0000 0174
                    70 0000 0000                70 0000 0400              31 0001 0001
                    00 0000 0000  0060          42 1400 0001  0150        06 0061 0217  0240
                    00 0000 0001                70 0217 0151              70 0000 0215
                    00 0000 0002                42 1603 1120              07 0000 0262
                    00 0000 0003                31 0162 1777              73 0000 0243
                    00 0000 0004                42 1603 1033              31 0001 0001
                    00 0000 0005                31 0163 1777              42 1404 0000
                    00 0000 0006                70 0000 0400              70 0000 0400
                    00 0000 0007                00 0000 0000              07 0000 1001
```

OVERLAY 35

```
01 0010 0202  0250
76 1767 1575
00 0000 0017                    70 0000 0560
77 1777 1760                    72 0505 0342
00 0000 0000                    72 0505 0343
00 0000 0377                    72 0505 0344
00 0000 0020                    72 0505 0345
00 0000 0020                    72 0505 0346
31 0060 1100  0260              72 0505 0347  0350
00 0002 0000                    72 0505 0350
00 0000 0011                    72 0505 0351
70 0000 0560                    72 0505 0352
72 0505 0263                    72 0505 0353
72 0505 0264                    72 0505 0354
00 0000 0000                    72 0505 0355
40 0000 0000                    72 0505 0356
41 0000 0000  0270              72 0505 0357  0360
01 0000 0000                    72 0505 0360
02 0000 0000                    72 0505 0361
04 0000 0000                    72 0505 0362
06 0000 0000                    72 0505 0363
10 0000 0000                    72 0505 0364
12 0000 0000                    72 0505 0365
14 0000 0000                    72 0505 0366
16 0000 0000  0300              72 0505 0367  0370
00 0000 0000                    72 0505 0370
42 1400 0001                    72 0505 0371
70 0217 0303                    72 0505 0372
42 1603 1042                    72 0505 0373
31 0301 17                      72 0505 0374
42 1404 C                       00 0231 0500
70 0000 0400                    00 0000 0035
31 0267 0301  0310
70 0000 0302
31 0271 0301
70 0000 0302
31 0272 0301
70 0000 0302
31 0273 0301
70 0000 0302
31 0274 0301  0320
70 0000 0302
31 0275 0301
70 0000 0302
31 0276 0301
70 0000 0302
31 0277 0301
70 0000 0302
31 0300 0301  0330
70 0000 0302
06 0271 0301
70 0000 0302
31 0270 0301
70 0000 0302
72 0607 0605
31 0414 0607
06 0062 0520  0340
70 0000 0400
```

```
                                                00 0000 0053  0070        00 0000 0020  0160
                                                00 0000 0037              72 0053 0150
                    70 0000 0646                00 0000 0077              05 0160 0000
                    70 0000 0472                20 0012 0001              31 0061 0157
                    70 0000 0660                00 0231 0600              70 0000 0155
                    70 0000 0667                00 0001 0400              00 0000 0016
                    70 0000 0501                70 0000 0404              00 0000 0000
                    70 0000 0523                00 0000 0070              00 0000 0013
                    70 0000 0000  0010          00 0000 0000  0100        31 0171 1400  0170
                    70 0000 0263                00 0000 0000              00 0000 0000
                    70 0000 0000                00 0000 0040              20 0002 0000
                    70 0000 0263                00 0000 0036              01 1600 0360
                    70 0000 0326                00 0000 0044              00 0000 0000
                    70 0000 0000                00 0000 0050              00 0770 0000
                    70 0000 0000                00 0000 0054              00 0003 1700
                    70 0000 0400                00 0000 0060              70 0000 0221
                    70 0000 0331  0020          00 0000 0064  0110        31 0167 0464  0200
                    70 0000 0000                00 0000 0041              07 0061 0167
                    70 0000 0000                00 0000 0045              25 0166 0000
                    70 0000 0000                00 0000 0051              34 0000 0000
                    70 0000 0000                00 0000 0055              05 0170 0210
                    70 0000 0000                00 0000 0061              07 0000 0103
                    70 0000 0000                00 0000 0065              30 0055 0171
                    70 0000 0000                00 0000 0042              31 0177 0220
                    70 0000 0000  0030          00 0000 0046  0120        31 0171 1400  0210
                    70 0000 0000                00 0000 0052              31 0063 0174
                    70 0000 0273                00 0000 0056              70 0000 0302
                    70 0000 0306                00 0000 0062              42 1430 0011
                    70 0000 0000                00 0000 0066              42 1002 0223
                    70 0000 0000                00 0000 0043              40 1377 0360
                    70 0000 0334                00 0000 0047              06 0173 1377
                    70 0000 0244                00 0000 0053              71 0174 0214
                    70 0000 0000  0040          00 0000 0057  0130        70 0000 0221  0220
                    70 0000 0000                00 0000 0063              31 0144 0155
                    70 0000 0000                00 0000 0000              72 0156 0161
                    70 0000 0000                00 0000 0067              36 0175 0171
                    70 0000 0000                00 0000 0070              07 0000 0103
                    70 0000 0000                00 0000 0071              30 0046 0000
                    70 0000 0605                00 0000 0000              36 0176 0171
                    70 0000 0000                00 0000 0000              72 0220 0210
                    33 0000 0000  0050          00 0000 0000  0140        71 0157 0311  0230
                    70 0000 0560                00 0000 0000              31 0145 0155
                    70 0000 0346                00 0000 0000              72 0156 0161
                    70 0000 0424                30 0063 0146              36 0176 0171
                    70 0000 0000                30 0055 0146              31 0210 0235
                    70 0000 0000                30 0046 0146              00 0000 0000
                    70 0000 0000                00 0000 0000              06 0061 0210
                    70 0000 0000                00 0000 0025              07 0000 0103
                    00 0000 0000  0060          72 0054 0400  0150        30 0063 0171  0240
                    00 0000 0001                05 0147 0000              72 0220 0210
                    00 0000 0002                36 0417 0153              71 0157 0317
                    00 0000 0003                07 0000 0000              71 0464 0250
                    00 0000 0004                31 0060 0157              06 0061 0166
                    00 0000 0005                30 0063 0146              70 0000 0200
                    00 0000 0006                70 0000 0156              00 0000 0000
                    00 0000 0007                00 0000 0000              00 0000 0000
```

OVERLAY 36

```
31 0001 0001  0250
31 0143 0155
72 0156 0161
07 0000 0103
30 0055 0171
06 0146 0171
72 0220 0210
71 0157 0321
70 0000 0221  0260
00 0000 0000
31 0060 0166
72 0272 0265
70 0000 0200
31 0211 1400
31 0060 1776
02 0061 0266
71 1400 0266  0270
72 0220 0275
70 0000 0000
72 0272 0265
70 0000 0331
31 0277 0266
31 0060 0171
31 0060 1776
31 0060 0166  0300
70 0000 0210
31 0172 1377
07 0000 0402
70 0050 0220
70 0000 0213
31 0172 1377
31 0063 0174
70 0000 0213  0310
72 0161 0231
72 0403 0401
73 0165 0162
31 0316 0161
70 0000 0161
72 0053 0150
72 0161 0243
70 0000 0312  0320
72 0161 0260
70 0000 0312
73 0165 0162
70 0000 0222
72 0505 0324
72 0220 0210
31 0177 0220
70 0000 0331  0330
31 0060 1400
31 0060 1000
70 0000 0400
31 0335 1361
31 0060 1377
02 0061 0335
71 1361 0335
42 1420 0010  0340
42 1006 0011
40 1361 0266
70 0074 0341
70 0000 0400
70 0000 0560
72 0607 0605
31 0414 0607
06 0062 0520  0350
70 0000 0400
70 0000 0506
72 0505 0352
72 0505 0353
72 0505 0354
72 0505 0355
72 0505 0356
72 0505 0357  0360
72 0505 0360
72 0505 0361
72 0505 0362
72 0505 0363
72 0505 0364
72 0505 0365
72 0505 0366
72 0505 0367  0370
72 0505 0370
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0231 0600
00 0000 0036
```

OVERLAY 37

```
70 0000 0646
70 0000 0472
70 0000 0660
70 0000 0667
70 0000 0501
70 0000 0523
70 0000 0101  0010
70 0000 0113
70 0000 0140
70 0000 0367
70 0000 0170
70 0000 0254
70 0000 0106
70 0000 0400
70 0000 0125  0020
70 0000 0152
70 0000 0000
70 0000 0225
70 0000 0233
70 0000 0241
70 0000 0243
70 0000 0245
70 0000 0247  0030
70 0000 0252
70 0000 0321
70 0000 0260
04 1773 0000
00 0000 0000
70 0000 0106
31 0001 0001
31 0063 0051  0040
42 1000 1271
40 1000 0777
70 1022 0043
70 0205 0052
42 1000 1411
71 0051 0041
42 1000 1211
70 0141 0052  0050
00 0000 0000
70 0000 0112
70 0000 0424
31 0001 0001
70 0000 0661
31 0001 0001
70 0000 0661
00 0000 0000  0060
00 0000 0001
00 0000 0002
00 0000 0003
00 0000 0004
00 0000 0005
00 0000 0006
00 0000 0007
00 0000 0053  0070
00 0000 0037
00 0000 0077
20 0012 0001
00 0231 0700
00 0001 0400
70 0000 0404
00 0000 0070
00 0000 0000  0100
42 1410 0015
31 0060 1000
70 0000 0353
41 1000 0777
70 0000 0400
42 1410 0017
31 0060 1000
70 0000 0037  0110
40 1000 0777
70 0000 0400
72 0657 0650
73 0000 0123
34 0000 1000
36 0571 0120
42 1420 0007
42 1007 0202  0120
41 1000 0376
70 0000 0400
07 0000 0676
70 0000 0115
07 0000 1376
72 0657 0652
73 0000 0136
34 0000 1000  0130
36 0571 0133
42 1420 0007
42 1000 0222
40 1000 0376
70 0000 0400
07 0000 0676
70 0000 0130
31 0061 0466  0140
72 0427 0423
72 0613 0610
05 0536 0000
36 0535 0147
31 0060 1000
42 1420 0010
42 1002 0000
41 1000 0100  0150
70 0000 0400
07 0000 1077
72 0613 0610
05 0536 0000
36 0535 0157
42 1420 0010
42 1006 0000
40 1000 0100  0160
70 0000 0400
00 0201 0000
00 0000 0000
00 0000 0477
00 0000 0035
00 0000 0000
70 0000 0254
72 0105 0101  0170
31 0414 0105
02 0167 1376
71 1376 0400
72 0105 0101
72 0135 0125
72 0105 0101
06 0061 1376
36 0067 0166  0200
30 0046 1375
03 0166 1376
30 0052 0000
04 0162 1375
34 0000 1375
72 0135 0125
71 0165 0177
72 0105 0101  0210
72 0161 0152
06 0061 1077
71 0164 0211
72 0105 0101
72 1042 1035
72 0105 0101
72 0135 0125
33 0000 0037  0220
72 0657 0652
70 0000 0661
72 0505 0222
72 0505 0223
42 1400 0001
70 0217 0226
42 1603 1001
42 1604 0000  0230
40 1000 0776
70 0000 0400
31 0060 0466
72 0427 0423
36 0417 0236
42 1414 0015
31 0001 0001
70 0000 0400  0240
42 1000 1211
70 0000 0400
42 1000 1231
70 0000 0400
42 1000 1411
70 0000 0400
42 1000 1271
```

OVERLAY 37

```
70 0000 0400  0250
72 0505 0250
42 1006 1411
70 0000 0400
42 1002 1211
70 0000 0400
00 0000 0107
00 0000 0040
31 0067 0464  0260
42 1410 0017
42 1000 1231
71 0464 0262
02 0257 0257
72 0657 0652
72 0122 0114
72 0112 0036
06 0061 0257  0270
73 0071 0265
42 1420 0010
42 1002 0300
41 1000 0777
72 0112 0106
02 0435 0273
71 0256 0272
31 0072 0256  0300
42 1420 0010
42 1002 0310
41 1000 0500
72 0112 0106
02 0435 0302
71 0256 0301
42 1410 0017
31 0001 0001  0310
31 0001 0001
42 1000 1271
31 0001 0001
07 0000 0071
72 0657 0652
70 0000 0054
00 0000 0000
00 0000 0107  0320
72 0105 0352
72 0135 0125
07 0061 1376
73 0071 0321
72 0105 0101
42 1420 0010
42 1006 0300
40 1000 0777  0330
02 0435 0327
71 0320 0325
31 0072 0320
72 0105 0101
42 1420 0010
42 1006 0310
40 1000 0477
02 0435 0336  0340
71 0320 0334
02 1400 1400
42 1410 0015
42 1002 1411
07 0000 0071
72 0657 0652
70 0000 0056
70 0000 0354  0350
72 0505 0350
70 0000 0101
70 1034 0354
31 0063 0051
42 1000 1211
41 1000 0777
70 1034 0365
42 1000 1411  0360
71 0051 0355
42 1000 1211
70 0141 0365
00 0000 0000
70 0000 0105
70 0000 0040
31 0060 1000
31 0060 1400  0370
70 0000 0400
72 0505 0371
72 0505 0372
72 0505 0373
72 0505 0374
00 0231 0700
00 0000 0037
```

## CATALOGUE FILE CARD

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|---|---|---|---|
| Rome Air Development Center, Griffiss AF Base, N.Y. Rpt No. RADC-TDR-63-160. AN ON-LINE COMPUTING CENTER. Final Rpt, 6 Mar 63, 118p, incl illus, tables.<br>Unclassified Report<br>An on-line computing system has been developed which allows direct use of a high speed digital computer by mathematicians and scientists in their specialized fields.<br>This report describes the system in detail from a user's point of view. For reference purposes, the report includes a listing of all computer programs used in the system. | 1. Computers<br>2. Digital computers<br>3. Input-output devices<br>4. Programming (computers)<br>I. AFSC Project 5581, Task 558104<br>II. Cont. AF30(602)-2762<br>III. Ramo Wooldridge<br>IV. G.J. Culler, B.D. Fried<br>V. In DDC collection | Rome Air Development Center, Griffiss AF Base, N.Y. Rpt No. RADC-TDR-63-160. AN ON-LINE COMPUTING CENTER. Final Rpt, 6 Mar 63, 118p, incl illus, tables.<br>Unclassified Report<br>An on-line computing system has been developed which allows direct use of a high speed digital computer by mathematicians and scientists in their specialized fields.<br>This report describes the system in detail from a user's point of view. For reference purposes, the report includes a listing of all computer programs used in the system. | 1. Computers<br>2. Digital computers<br>3. Input-output devices<br>4. Programming (computers)<br>I. AFSC Project 5581, Task 558104<br>II. Cont. AF30(602)-2762<br>III. Ramo Wooldridge<br>IV. G.J. Culler, B.D. Fried<br>V. In DDC collection |
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